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BOMBARDIER SINGLE-CYLINDER MEDIUM-SPEED RESEARCH ENGINE AND TEST FACILITY - PHASE IV

DEVELOPMENT OF L.O.E. ENGINE AND TURBOCHARGER RIG

Prepared for
TRANSPORTATION DEVELOPMENT CENTRE,
POLICY AND COORDINATION GROUP
TRANSPORT CANADA

DEC

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Un sommaire en français de ce rapport est inclus avant la Table des matières.

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16. Abstract

This report covers the fourth phase of the Bombardier Single-Cylinder Research Engine program supported by the Transportation Development Centre. The prior three phases pertained to the single-cylinder test facility, including the fuels and lubricants laboratory. This portion of work includes the design and building of the Lubricating Oil Evaluation version of the research engine, the completion of the turbocharger test cell and the preparation of an operational documentation package. A description of the engine and turbo test rig operation is given with commissioning data where applicable. In addition, samples of the documentation are included.

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16. Resumé

Ce rapport concerne les travaux de la quatrième phase du programme de développement du moteur monocylindre expérimental lancé par Bombardier Inc. et coparrainé par le Centre de développement des transports. Les phases antérieures concernaient l'étude du moteur et de son banc d'essai, leur fabrication, leur mise en place et leur caractérisation comme outils de recherche et de développement, ainsi que l'installation d'un laboratoire d'analyse des carburants et lubrifiants. La phase IV a porté sur l'étude et la construction d'une version du moteur expérimental adaptée pour l'essai des lubrifiants, sur le parachèvement du banc d'essai du turbocompresseur et sur la préparation des documents d'exploitation, expliquant le fonctionnement du moteur et du banc d'essai du turbocompresseur et indiquant les réglages de mise en service lorsqu'il y a lieu. Des exemples de cette documentation sont joints au rapport.

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SUMMARY

The need for continued research and development to enhance diesel engines is approaching the critical stage. Current and pending North American environmental regulations are placing efficiency and usage restrictions on the diesel engine. These restrictions can only be overcome when the interactions of the whole diesel engine system are fully understood; for example, the influence of lubricating oil quality on exhaust emissions. The 1981 and 1984 American Environmental Protection Agency (EPA) regulations impose severe limits on particulates released in the atmosphere. These regulations require low consistent oil consumption since approximately 70% of the particulate emissions are due to burning lubricating oil. Although these regulations apply currently to heavy-duty highway engines, they are expected to be applied to the off-highway sector in the near future.

The Lub Oil Evaluation (LOE) version of the Bombardier Single-Cylinder Research Engine (BSCRE) was designed and developed as an aid in understanding lubricating oils and their performances.

This report describes the development of the Bombardier Single-Cylinder Research Engine/Lubricating Oil Evaluation (BSCRE/LOE) version, and the development of turbocharger test rig. Both are requisite to medium-speed diesel engine research.

The LOE engine employs four separate lubricating oil circuits:

- power train;
- balance shafts;
- camshaft/valve gear;
- gear train.

This design feature allows for the testing of component-specific lubricant formulations. The four oil supplies and returns can be externally connected to common manifolds, thereby simulating the one inlet/one outlet configuration of a typical engine.

Development of the Turbocharger Test Rig (TTR) started during the previous phase, which consisted of the design, manufacture of some components and the construction of the test cell. The work covered in the current phase includes completion, installation and proof-of-design testing of the turbocharger rig and its auxiliary supporting systems control. The TTR is capable of functioning in three modes: the closed loop, the open loop, and any combination of the open and closed loop (mixed mode).

During the current phase of work, two additional tasks were completed: a comprehensive BSCRE users' documentation package and the addition of an atomic absorption spectrophotometer to the Fuels and Lubricants Laboratory.

SOMMAIRE

La nécessité de pousser la recherche et le développement dans le domaine de la technologie des moteurs diesel se fait de plus en plus pressante. La réglementation nord-américain en matière de protection de l'environnement impose déjà certaines restrictions quant à l'usage des moteurs diesel et certaines exigences quant à leur rendement. On ne peut espérer échapper à ces contraintes qu'à la condition d'acquérir une parfaite connaissance et une bonne maîtrise de l'interaction entre les divers éléments constitutifs du diesel; par exemple, du rapport entre la composition des lubrifiants et les produits de combustion. Les règlements formulés par l'American Environmental Protection Agency (EPA), en 1981 et 1984, sont sévères quant aux quantités de particules pouvant être émises dans l'atmosphère. Ces derniers incitent à la recherche d'une faible consommation d'huile, puisque celle-ci compte pour environ 70% des produits de combustion des moteurs diesel. Bien que cette réglementation ne s'applique encore qu'aux poids lourds circulant sur les grandes routes, on s'attend à ce qu'elle devienne universelle dans un proche avenir.

C'est dans cette optique qu'une version du moteur expérimental de Bombardier a été spécialement étudiée afin d'évaluer le rendement des lubrifiants.

Le présent rapport décrit donc les travaux de développement de cette version adaptée du moteur diesel monocylindre et de perfectionnement du banc d'essai du turbocompresseur, tous deux indispendables à la recherche sur les moteurs diesel semi-rapides.

La nouvelle version du moteur expérimental comprend un circuit indépendant de lubrification pour chacun des quatre dispositifs suivants:

- embiellage;
- arbres d'équilibrage;
- arbre à cames/commandes de soupapes;
- train d'engrenages.

Cette disposition constructive permet d'évaluer l'efficacité des lubrifiants en fonction de chacun des dispositifs considérés. Les quatre canalisations d'alimentation et de retour peuvent être raccordées à l'extérieur à des collecteurs communs, de manière à reproduire la disposition normale, soit une seule canalisation d'entrée et une seule canalisation de sortie.

Le développement du banc d'essai du turbocompresseur avait été entrepris lors de la phase précédente du programme. Certains éléments avaient alors été étudiés, puis fabriqués et la construction du banc commencée. Au cours de la présente phase, le banc d'essai a été parachevé, mis en place et soumis aux essais de validation de principe avec tous ses appareils de mesure et de contrôle. Ce banc d'essai se prête à trois modes d'alimentation: en circuit ouvert, en circuit fermé, ou en circuit mixte, c'est-à-dire selon toutes les combinaisons voulues des deux circuits précédents.

Par ailleurs, les deux tâches suivantes ont été complétées: les documents d'exploitation et le laboratoire d'analyse des carburants et lubrifiants doté d'un spectophotomètre d'absorption atomique.

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1. INTRODUCTION

The conception of a single-cylinder research engine arose from a need for major improvement in all areas of diesel engine technology. Programs to develop the Bombardier B2400 and 251-plus (an improved version of the Alco 251 engines) were initiated in response to this need.

Supported by Transportation Development Centre (TDC) funding, the Bombardier single-cylinder research engine (BSCRE) program began in 1982.

The modal objective of this program was to develop, through the use of a single-cylinder research engine, locomotive engines which are fuel efficient and capable of burning alternative and off-specification fuels. Within the scope of the modal objective is the establishment of a research and development facility which would be capable of addressing locomotive engine testing and development engineering. The evolution of the BSCRE facility is documented in references [2], [3], [4] and [5].

This report describes the work executed in phase IV. The achievement described can be considered as the final activity in fullfilling the aforesaid objectives. Included in this work are: the preparation of a documentation package which consists of maintenance instructions, replacement parts catalog, running-in instructions and a descriptive brochure; the design and building of lubricating oil evaluation (LOE) version of the BSCRE and the completion and commissioning of the turbocharger test cell.

In addition to the above, this phase includes the acquisition of a microprocessor controlled atomic absorption spectrophometer which measures the concentration of metallic elements in a variety of matrices. This instrument will be utilized primarily in the detection of wear metals in lubricating oil.

2. DISCUSSION

2.1 Engine Documentation

With the purchase of the BSCRE by SouthWest Research Institute (SWRI) and by the National Research Council of Canada (NRC), it became necessary to prepare a complete documentation package to inform the user of the maintenance required to keep the engines in proper operating condition. To comply with the above, a single-volume Maintenance Instruction (MI) manual was compiled covering the removal, replacement and fitting of components denoting their respective dimensional limits and fits. A catalog of replacement parts was also created to facilitate user component identification. Following Bombardier's convention, the catalog is made up of Diesel Replacement Parts (DRP's) in which special tools are identified and catalog numbers are given where necessary. Appendix A consists of the MIs and DRPs making the BSCRE manual.

A descriptive brochure which could be suitable for promotional literature and also serve to explain the LOE engine concept was included in the documentation package (see Appendix A).

2.2 LOE Engine Development

2.2.1 Concept

During the initial stages of the design and conceptual analysis of the BSCRE, it was observed that, when analyzing the tribological effect and performance of the lubricating oils throughout the engine, conflicting studies resulted, specifically when using multi-viscosity oils.

To address these conflicting results, the critical question: "Do these lubricants perform equally through the engine system?" needed to be answered.

The published literature of oil refiners and additive suppliers supported both sides of the argument. The high speed diesel engine sector was faced with a similar dilemma. Caterpillar [1] chose AVL to redesign their single-cylinder research engine so that specific engine areas could be lubricated separately. The BSCRE was designed so that the development of the LOE version, which employs four separate lubricating oil circuits, would be a natural progression and therefore give the medium-speed diesel engine sector the needed flexibility and capability to answer the question. Photographs of the BSCRE-LOE engine can be seen on pages 3 and 4.

2.2.2 Design

The five fundamental requirements which formed the design philosophy of the basic BSCRE [2] are maintained in the LOE version. They are:

- Representative of the Bombardier engine
- A research tool
- Flexibility
- Accessibility
- Maximum use of off-the-shelf components.

Figure 1 - Bombardier Single-Cylinder Research Lube Oil Version in the Test Facility

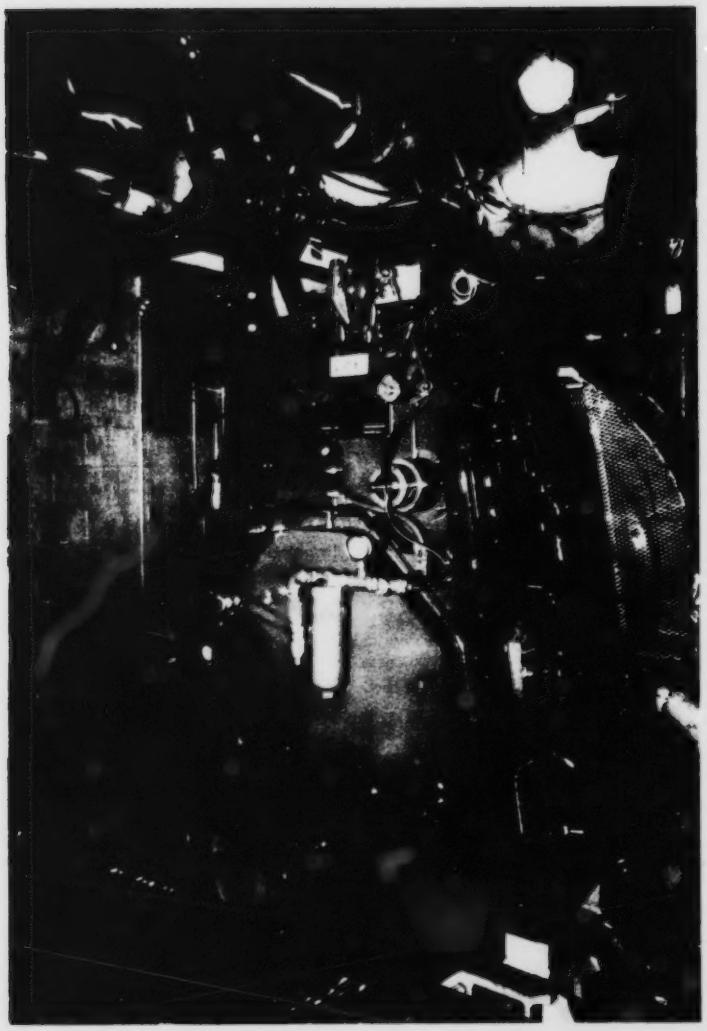


Figure 2 - Close-up of the LOE Engine

Since the LOE engine is a variation of the basic BSCRE, only those areas which were changed will be described. Longitudinal and transversal cross-sections of the two versions are shown in Figures B.1 and B.2, Appendix B.

The cylinder block is of welded steel construction. Within the cylinder block is the camshaft and its drive gear train. In general practice, a secondary header supplies lubricating oil to the cylinder head valve gear which then drains down the push rod cavity and lubricates the camshaft assembly. The same header directs oil to the camshaft drive gears through a spray nozzle. These two systems are separated in the LOE engine by means of individual oil supplies, returns, oil seals and partition plates. These features can be seen in Figures B.3 and B.4, Appendix B.

It was recognized from the start that design changes would be needed in order to isolate the three systems which make up the crankcase assembly. The bed plate type crankcase is a welded construction with three cast steel cross webs that support the three crankshaft main bearings. Located below the crankshaft is the balancing shaft arrangement consisting of two primary and two secondary contra-rotating systems. At the front and rear of the crankcase are gear sets which drive the balancing shafts and the main cam drive gear respectively.

A divider plate was designed to separate the power assembly from the balancing shafts. Oil from the piston, bearings and cylinder walls is contained in this compartment which can be considered as a dry sump (see Figures B.6, Appendix B). Accuracy of lube oil analysis is sometimes dependent on recapturing a very high percentage of the candidate test oil; therefore, the shape of the divider plate causes quick and maximum drainage back to the holding tank.

Isolating the power assembly meant devising a method of preventing oil from the power assembly and crankshaft bearings from mixing or being contaminated. Double lip seals were chosen because of their off-the-shelf availability and cost, but the crankshaft was redesigned to accept higher performance seals without additional design changes if seal life was not satisfactory. Space was required to fit the seals, therefore resulting in an increase in the overall crankshaft length. As shown in Figure B.5, Appendix B, seals are fitted into a retaining ring which is fastened to the cross webs. Wear sleeves are installed on the crankshaft, allowing for normal seal and shaft wear without the need for crank replacement. Drain passages were designed to avoid oil retention and pressure in the seal pockets.

Compared to the power assembly, isolating the balancing shaft system, oil circuit was straightforward. Two front cross webs and the crankcase divider plate formed an enclosure only. An oil sump modification was required to close the compartment. Lubricating oil enters the front sleeve bearing through a passage in the cross web, then travels through the shaft drilling to the rear sleeve bearing. Oil is contained in the balance shaft system by an oil double lip seal at the front and an end cap at the rear. All of the oil circulating in the balance shaft system is captured by the front oil sump which is connected to the pump suction side.

Lubrication of the two gear sets is accomplished by nozzle spray supplied by a single oil header. The rear compartment contains the camshaft drive gear set. A gear cover at the front encloses the balancing shaft gears. Drains from both gear trains are connected externally to a single oil return.

Note: For further clarification of the separate lubricating systems, refer to the brochure BSCRE in Appendix A, Section A-1.

Figures B.8 in Appendix B show the lubricating oil pipe arrangement including supply (oil feed) and return oil lines. Also shown are the individual circuits which make up the complete lube oil system as installed in the test cell. Since there were no immediate plans for multi-lube testing after initial proof testing, oil-supply and oil-return manifolding of the four circuits allow the LOE engine to function with a single pump, similar to the BSCRE 1-251.

2.2.3 Proof of design test

To verify the segregation of the engine lube oil circuits, a test procedure was prepared (see Appendix C) after various techniques were considered, including ultra-violet dyes and metallic doping. Each of these methods contained a degree of complexity but could be used with the engine running (dynamic conditions). Due to time restrictions and the ease of visual inspection of the seals and compartment dividers, the test procedure is based on observing the integrity of the seals, drains and isolating partitions at increasing oil flows and pressure with and without the engine being barred over.

From the recorded results of the test, it can be stated that the design objectives of isolating the four main engine mechanical groups were achieved. However, some refinement of the lube oil return lines is necessary. It was found that gravity dependent drains were inadequate from mid-range to full speed and load. To overcome this situation, an evacuation pump was installed at the power assembly, valve train and camshaft return outlet.

2.3 Turbocharger Test Rig

2.3.1 Concept

The BSCRE in any of its design variants offers the development capability of engine component and in-cylinder process analysis. Both the 251 and B2400 engine families are turbocharged, therefore the need for understanding the influence and performance of the Bombardier turbochargers is of great importance. Also it is necessary that as the performance and efficiency of the engine advances so must the turbocharger.

A single-cylinder engine cannot sustain a turbocharger, consequently a turbo rig is required as a parallel and complementary development tool.

The Turbocharger Test Rig (TTR) has the capability of operating in three different modes. The open loop mode where air is supplied to the combustor from an external air source and then supplied to the turbine, while the air produced by the turbocharger compressor is exhausted to a dump room or to the atmosphere. The closed loop mode where the turbocharger compressor delivers air to the turbine via the combustor. The mixed mode where air from both compressor and external air supply is fed to the turbine via the combustor. This three-mode capability provides the most economical method to obtain data from either the turbine or compressor away from their natural match. Photographs of the TTR can be seen on pages 7 and 8.

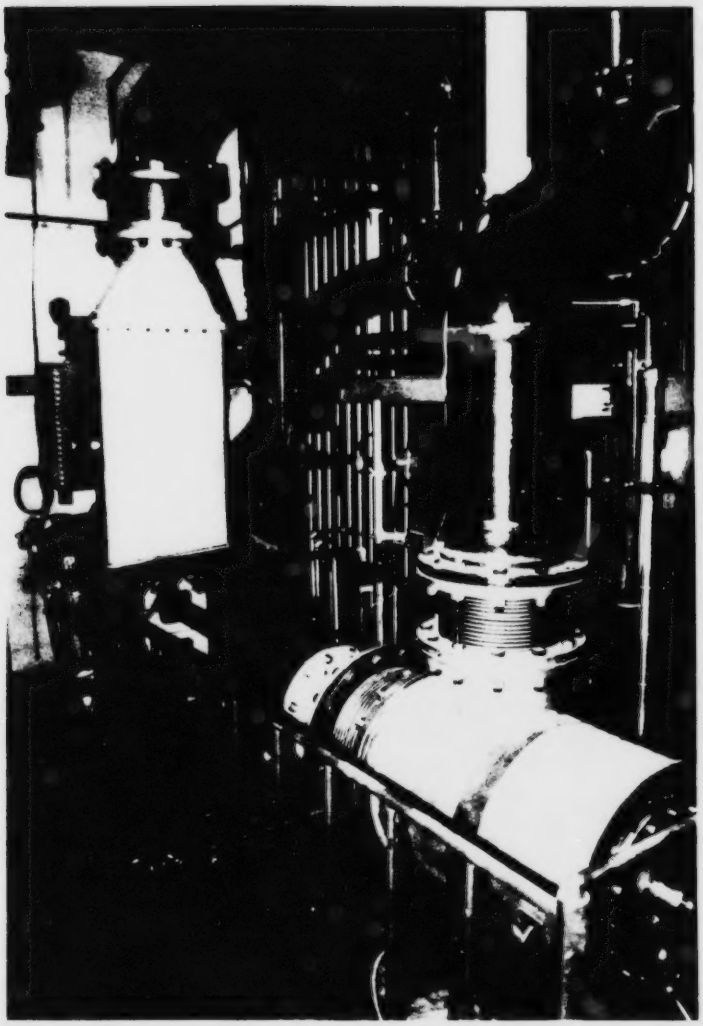


Figure 3 - Side view of the turbocharger test cell

Close-up view of the combustor and the air duct inlet to the combustor along with its expansion joint. Also clearly visible, the exhaust manifold arrangement, the turbocharger, the exhaust piping, the air control valves and the circuit.

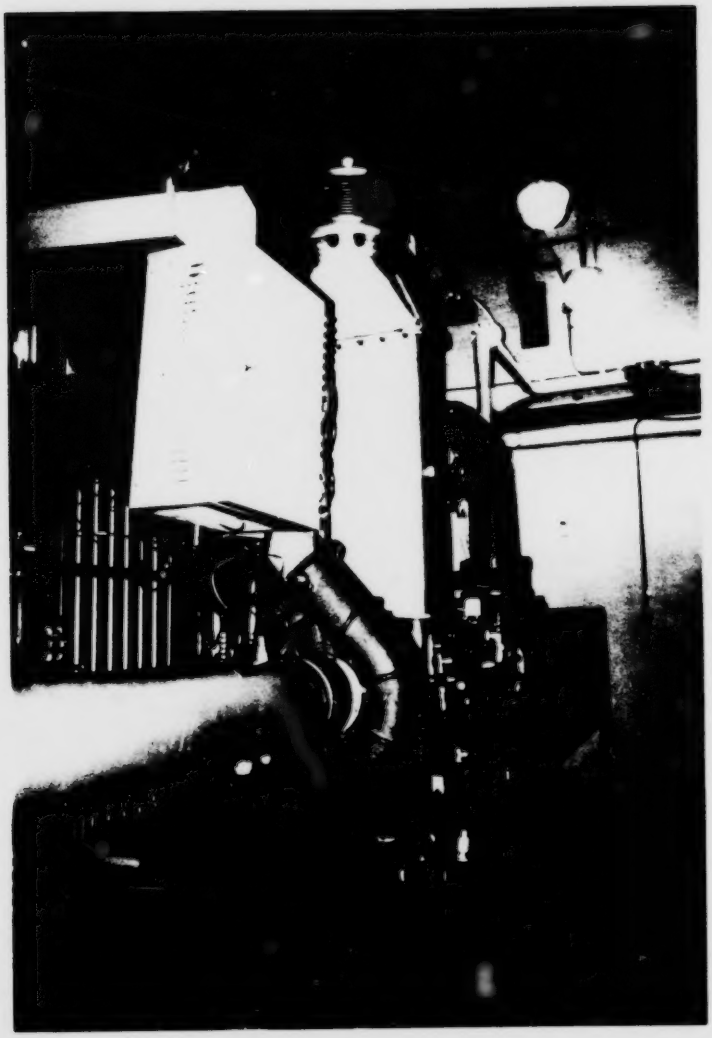


Figure 4 - Front view of the turbocharger test cell

Clearly visible, the air inlet duct, front view of the turbocharger and its support, and the TTR control box

2.3.2 Design

The conceptual design of the TTR was broken down into the following main components and circuitry:

- Tubocharger support
- Combustor
- Combustion air supply system
- Gas circuit
- Fuel supply system
- Lubricating oil system
- Cooling water system
- Controls and instrumentation.

A comprehensive description of the design of the previous items is given in the report covering Phase III, reference [5].

Appendix D shows the general circuit, the general arrangement and the start-up procedure respectively. In general, the TTR has been designed to have a mass flow rate capacity as follows:

- One to 3 lb/s (0,454 kg/s to 1,36 kg/s) for the open loop
- Three to 17 lb/s (1,36 kg/s to 7,71 kg/s) for the mixed and closed loops

The combustor parameters operate effectively over the following ranges:

- Air mass flow, from 1 to 17 lb/s (0,454 kg/s to 7,71 kg/s)
- Pressure up to 65.0 psia (448,0 kPa)
- Pressure drop does not exceed 5%
- Gas temperature 1100°F (593°C) nominal and 1350°F (732°C) maximum

Capable of burning diesel, heavy fuel, and natural gas fuel.

A lower limit operating condition was set to an air main flow rate of one lb/s (0,454 kg/s) @ 100°F (37.8°C).

To successfully operate the TTR in the three different modes, as previously described, a two-way valve is used to direct the compressed air to either the combustor, ambient or divide the flow between both. The installed valve is located at a convenient location between the combustor and the dump pipe, and as far away from the compressor discharge control valve as practically possible. The make up air pipe is connected to the main pipe at a location of six feet (1,8 m) from the combustor flange.

The design of the TTR air circuit is such that the total pressure drop (loss) at the entry of the compressor does not exceed 15 inches (38 cm) of water. Also, total pressure drop from the compressor discharge to the inlet of the combustor in the closed loop mode does not exceed 6% of compressor discharge.

Design requirements included the insulation of all pipes and hot surfaces. However, it was preferred to complete testing and commissionning before applying the insulation.

2.3.3 Proof of test rig design

Verification of the cooling, fuel, lubricating oil, and combustion air systems was performed individually and then simultaneously as they would during operation.

A test procedure based on the parameters (mass flow, exhaust temperatures, and turbine speed) of an engine installed turbocharger was prepared. The test procedure also defines in great detail the starting and operating sequence of events for proper TTR utilization.

Since this turbocharger rig is a unique and improved design, the major difficulty revolve around optimizing the start-up set points, air/fuel ratios being the most critical. This was accomplished by carefully balancing the pneumatic control valves that regulate air and gas flow in all three system operating modes.

During each of the tests, thirty-four data points were recorded including a room temperature reading which reached as high as 131°F (55°C) at the ceiling location. Observed results indicate the following:

- All three modes of operation are functional.
- Using shop air only (no combustor), the installed 165 turbochargers could be spun to 3000 RPM.
- Combustor ignition was acheived at a turbo speed of 1300 RPM with the fuel control valve set at 25% and a fuel pressure of 50 psi (334,7 kPa). With the system warm, restart could be achieved at 2700 RPM with a fuel setting at 30%.
- Best closed loop operation was noted at 8050 RPM with a fuel setting of 50% at 50 psi (344,7 kPa) shop make up air was 40%.
- In the self supporting regime (no shop air), maximum RPM reached was 6300. A turbo gas causing temperature of 545°F (285°C) was observed.

From the above data, it can be stated that the design concept was proven. However, additional refinements and calibration of the existing equipment is needed in order to achieve more realistic and consistent results.

2.4 Test Equipment

A minor activity within the scope of this project was the acquisition of an Atomic Absorption Spectrophotometer (AAS). This precision instrument measures the concentration of metallic elements in a variety of matrices. It will be used primarily to detect wear metals in engine lubricating oil. With the installation of the AAS, the fuels and lubricants chemistry laboratory in conjunction with the LOE engine is now capable of investigating all fuel and lubricating oil characteristics related to railroad diesel engines.

3. CONCLUSION AND RECOMMENDATIONS

Two unique research tools were designed and developed. Both the LOE engine and the turbocharger test cell will allow for comprehensive research and development to be performed in the medium-speed sector. Users of the LOE engine will now be able to focus on lube oil formulations specific to mechanical components within an engine. In addition, influence of lubricating oil in the combustion process and its impact on the production of particulates can be precisely addressed.

It is recommended that additional work be performed to define the optimum LOE engine compartment drain configuration, and it is also recommended that the base lubricating oil pressures be established.

Pertaining to the TTR the following is recommended:

- Install air mass flow measuring devices in the compressor air intake, make up air, and recirculation air cuircuits
- Increase fuel flow capacity
- Install smoke meter
- Install thermal insulation
- Install ventilation system
- Improve capability of charging out turbochargers.

In summary, it can be stated that the objective of this project has been satisfied. The development of a medium-speed lube oil evaluation engine will certainly enhance future research and development in the fields of emissions and tribology. The TTR and the single engine are tools that are needed today to research and investigate the realism of diesel engine technology, and ways to improve engine performance and efficiencies above the state of the art values. In addition, results of this Phase IV of the Bombardier single-cylinder medium-speed research engine and test facility, establishes a fully integrated medium-speed diesel engine test centre.

REFERENCES

1. Versatile single-cylinder diesel test engine for lubricant, Emission and Fuel Research. J.R. Griffin, Chevron Research Company; H.L. Wittek, List-Rosen-Wittek Associates Inc. SAE 730831, 1987.

2. Design of a single-cylinder medium-speed research engine and test facility. Transport Canada Report #TP4844E, M.L. Payne, Bombardier Rail and Diesel Products Division, August 1983.

3. Design of a single-cylinder medium-speed research engine and test facility. Transport Canada Report #TP4844E Addendum, M.L. Payne, Bombardier Rail and Diesel Products Division, March 1985.

4. Single-cylinder medium-speed research engine and test facility. Transport Canada Report #TP6876E, M.L. Payne, Bombardier Rail and Diesel Products Division, July 1985.

5. Single-cylinder medium-speed research engine and test facility. Transport Canada Report #TP8395E, M.L. Payne, Bombardier Rail and Diesel Products Division, 1987.

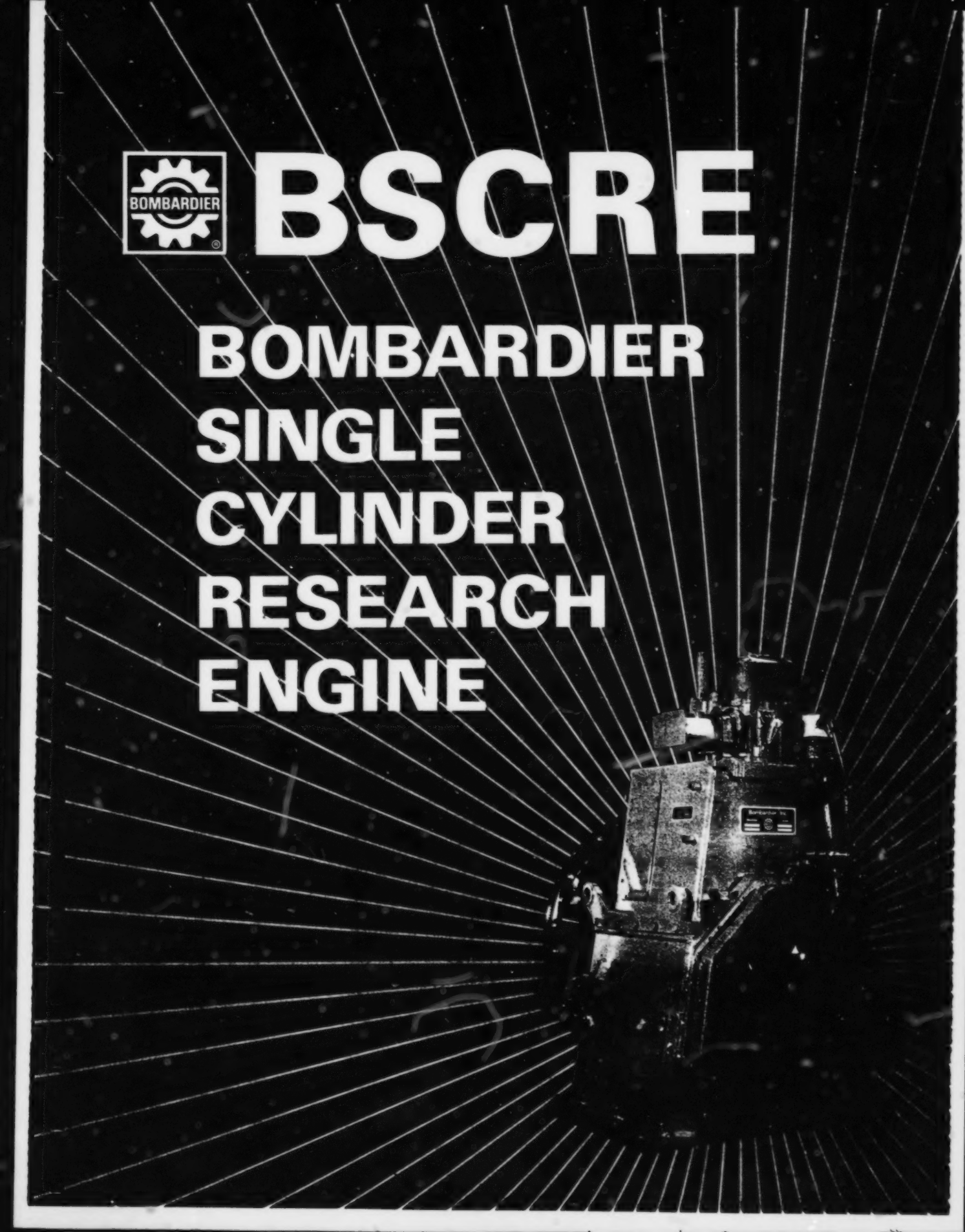
APPENDIX A ENGINE BROCHURE AND MAINTENANCE CATALOG

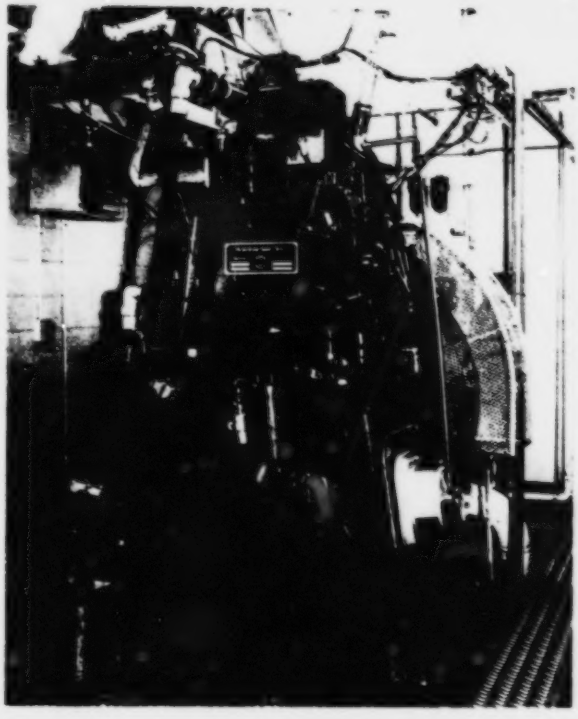
A-1 Engine Brochure

A-2 Maintenance Instructions and Catalog

BSCRE

BOMBARDIER SINGLE CYLINDER RESEARCH ENGINE





Why a research engine?

Successful diesel engine builders recognize the importance of ongoing development work in combustion, performance, wear, fuel and lubricants. Oil processors see this need too; and so do a large number of institutions, manufacturers and research personnel all deeply involved in the world-wide search for higher efficiencies of energy use.

Bombardier Inc., aided with funding in part by the Panel on Energy Research & Development administered by Transport Canada, undertook the development of a single-cylinder research engine.

Why single-cylinder?

The smaller and simpler single-cylinder engine offers researchers all the important design and operating characteristics of its multi-cylinder counterpart. Precise test conditions, needed for tight control, can be set up more easily, and that encourages a broader choice of experimental work. Much lower costs are achieved, from initial purchase and installation to the savings in labor, fuel, and spare parts.

What are the Bombardier benefits?

We offer two research engines — the Bombardier single-cylinder research engine (BSCRE) and lube oil evaluation engine (BSCRE/LOE). Both are research diesel engines uniquely designed to represent our medium-speed, 4-stroke series of production engines.

Some specific benefits include:

- Superior structural strength for severe conditions.
- Easy access for installing special instrumentation.
- Wide range of adjustments — all support systems operate independently of engine.
- Minimal instrumentation and only one set of experimental parts needed.
- Ease of inspection for crankshaft main bearings and balancing system.
- Straightforward adjustment or removal of camshaft.
- Separate upper and lower liner cooling water inlets for testing off-spec fuels.
- Design accepts future horsepower upgrades, as well as different top works to permit 2-stroke research.

All power-assembly components of the BSCRE and BSCRE/LOE are standard components of the ALCO 251, a proven prime mover being used in a variety of applications worldwide. Having design features and parts in common with multi-cylinder production engines means that test data from the research engines can be correlated with data derived from the real world.

Mechanical simplicity provides for easy access to the cylinder liner, head and bottom end for installing special instrumentation. And since all support systems operate independently of the engine, a wide range of adjustments can be made to intake air, cooling water, and lubricating oil pressure and temperature.

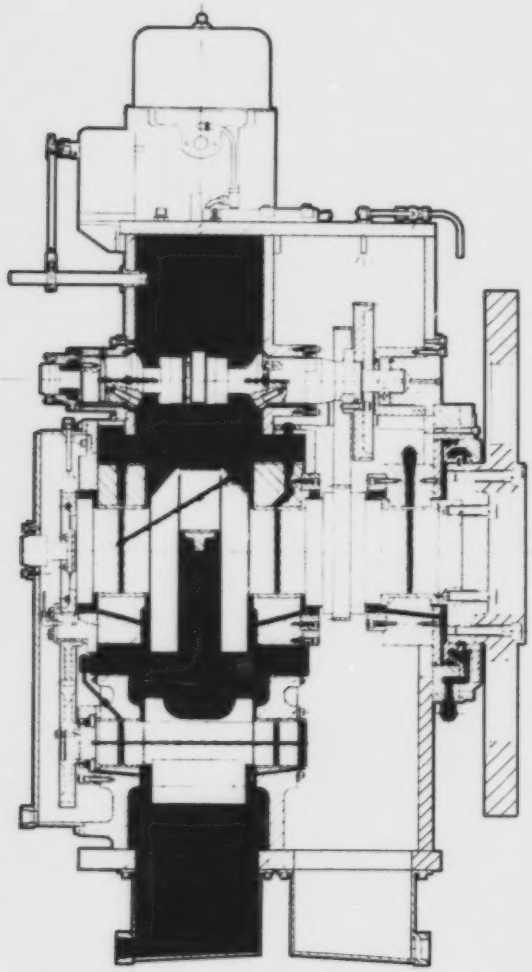
All shafts, including the crankshaft and camshaft, are pre-drilled and tapped at the free end for fitting PTO shafts.

An electric governor, compatible with computerized engine management systems, permits the close control of engine speed that is so important for accurate and repeatable test results.

Why four lube systems for the BSCRE/LOE?

Four types of oil can be tested with the following separate lubrication systems:

- POWER TRAIN: crankshaft, main bearings, thrust bearings, connecting rod bearings, piston pin, and piston.
- BALANCE SHAFTS: balance shaft bearings.
- CAMSHAFT: rocker arms, valve guides, push-rods, lifters and cams.
- GEAR TRAIN: camshaft drive train, and balance shaft drive train.



VIEW: FRONT TO BACK — LOE ENGINE

All four oil supplies can be externally connected to a common manifold allowing basic research testing capabilities. The wet sump, with sloping sides and bottom, prevents retention of the oil under test; this design also promotes circulation if a dry-sump system is used.

What are the cost savings?

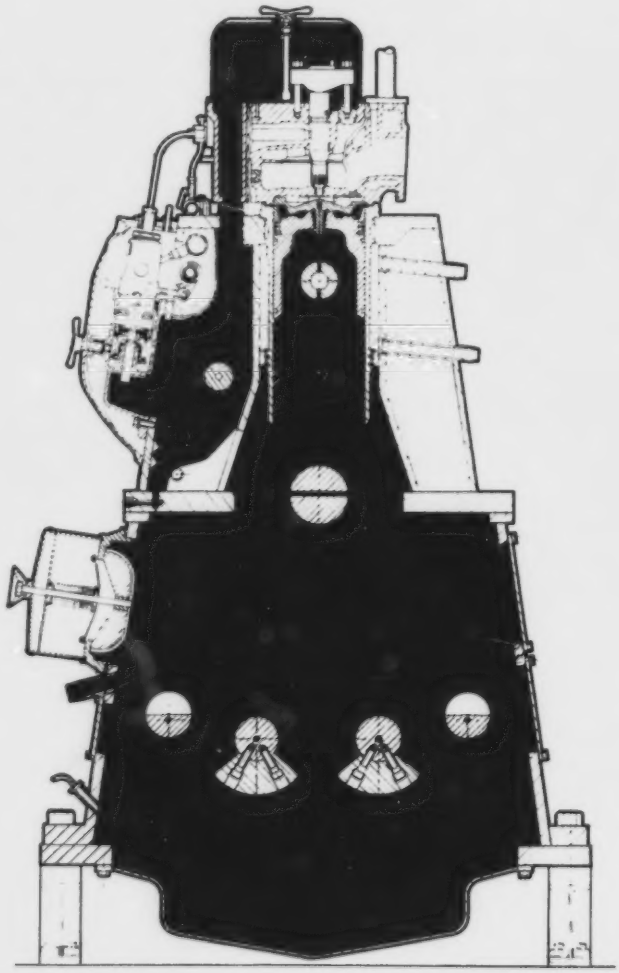
The Association of American Railroads, in a cost study, found that an off-spec fuel could be performance tested in two days using a BSCRE at a cost of about $1200 (1986$) and consuming 100-150 gallons of test fuel. That same performance test with a 12-cylinder engine, said the AAR, would cost $3,300 and consume 1200 to 1500 gallons of test fuel.

Engine-wear studies, too, can yield a similar magnitude of savings. A 500-hour test (considered the minimum to achieve measurable wear) costs $100,000 or more per 12-cylinder engine. Using a BSCRE, the comparable test would cost about $45-50,000. And compared with the 43,000 gallons of fuel for the 12-cylinder engine, only 3,500-4,000 gallons would be used by the BSCRE.

Is there anything else?

There is a helpful organization of researchers known as the "Bombardier Single-Cylinder Research Engine Users' Group." The Group agrees to hold meetings twice a year to present and discuss their research projects and results relative to the peformance of the BSCRE as a research tool. Purchase of either research engine automatically enrolls you in the "BSCRE-UG," whose membership represents such organizations as Southwestern Research Institute, the American Association of Railroads, and the National Research Council of Canada.

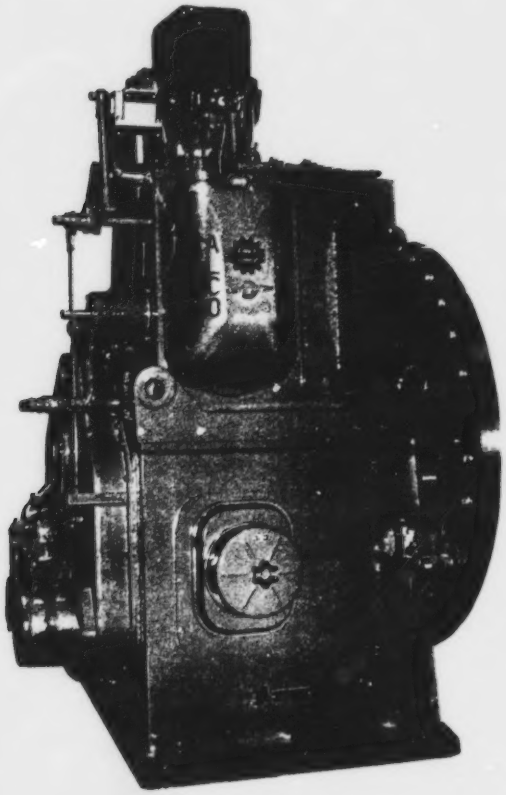
Finally, Bombardier can discuss with you numerous tests that would not even be feasible with a multi-cylinder engine; and, of course, we are equipped and prepared to work with you right now, whether shipping you an engine or designing and installing a complete test facility to your specific requirements.



VIEW: SIDE TO SIDE — LOE ENGINE

BSCRE Design Specifications

Engine Configuration	ALCO 251
Bore & Stroke	228.6 mm x 266.7 mm (9 in x 10.5 in)
Displacement	11.00L (668 cu. in.)
IMEP (max.)	23.0 bar (334 psi.)
P_{max}	145.0 bar (2103 psi.)
Crankshaft Journal Dia.	216 mm (8.5 in.)
Crankpin Dia.	152.4 mm (6.0 in.)
RPM (max.)	1500
Piston speed	10.66 m/s (35 ft./s)
RPM (idle)	200
Overspeed	10% (30% without failure)
Lube oil capacity	132L (35 US gal.)
Water capacity	57L (15 US gal.)



Engine Data Sheet

Model: 251-Plus*

Model number	1-251-Plus
Rated output	369 kw (275 hp)
RPM	1100
Bore	228.6mm (9 in.)
Stroke	266.7 mm (10.5 in.)
Compression ratio	12.5 to 1
Crankshaft rotation (viewed from drive end)	Counterclockwise
Camshaft overlap	140°
Fuel injection nozzle:	
number of holes	9
size of holes	375 mm
spray angle	157°
Fuel injection pump	18 mm
Fuel injection timing	24°BTDC
Governor	Barber Coleman Dync 14000-0-0-24

*As shipped

For more information, contact one of the following:

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Auburn, N.Y.,
U.S.A.

MAINTENANCE MANUAL & PARTS CATALOGUE

ASSOCIATION OF AMERICAN RAILROADS

SALES ORDER 3211

SINGLE CYLINDER

DIESEL RESEARCH ENGINE

ENGINE MODEL 1-251-PLUS

SERIAL NO. BSCRE-4

NOVEMBER 1986

Data subject to change without notice.

MAINTENANCE MANUAL & PARTS CATALOGUE

ASSOCIATION OF AMERICAN RAILROADS

This manual is a combined Maintenance Manual and Parts Catalogue. It is divided into three sections as follows:

SECTION 1 – Data
SECTION 2 – Engine Maintenance
SECTION 3 – Engine Renewal Parts

In Sections 1, 2 and 3, Maintenance Instructions and Parts Bulletins are inserted in numerical sequence. Drawings are inserted at the end of the section.

Information furnished is based upon construction as of date of publication. Some minor differences may be encountered between these instructions and the actual equipment due to refinements in equipment engineering after publication.

Revision pages will be forwarded to the user in order to provide the latest maintenance and parts information. Unless otherwise instructed, these revisions will be forwarded to:

Association of American Railroads
Research and Test Department
50 F Street N.W.
Washington D.C., U.S.A.
20001

If additional of different distribution is required, please direct your requests to the below address:

Bombardier Inc.
Rail and Diesel Products Division
Technical Publications
1505, Dickson St.
Montreal, Quebec, Canada
H1N 2H7

MANY OF THE MAINTENANCE INSTRUCTIONS
CONTAINED IN THIS MANUAL ARE FOR
MULTI-CYLINDER ENGINES.
THEY MAY NOT APPLY TOTALLY TO
YOUR ENGINE AND, THEREFORE,
SHOULD BE USED FOR REFERENCE ONLY.

MAINTENANCE MANUAL AND PARTS CATALOGUE

MM/MC-87

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DATA SHEET - STATIONARY ENGINE
1-251-PLUS

GENERAL

Engine number	BSCRE-04
Model number	1-251-PLUS
Number of cylinders	one
Bore	228.6 mm (9 in.)
Stroke	266.7 mm (10-1/2 in.)
Compression ratio	12.5:1
Crankshaft rotation (viewed from drive end)	Counterclockwise
Camshaft overlap	140°
Fuel injection equipment, injector nozzle: no. holes, size, spray angle	9, 0.375 mm, 157°
Injection pump	18 mm
Fuel pump timing	24° BTDC
Governor	Barber Coleman Dync 14000-0-0-24
Heater:	
Jacket water immersion	3 kW
Lubricating oil immersion	3 kW
Output, rated:	
100%	275 BHP
110%	300 BHP
Speed, rated engine:	
100%	1100 RPM
110%	1210 RPM
Starter	Air motor

CAPACITIES

Engine:	
Lubricating oil	132 L (35 US gal.)
Water	57 L (15 US gal.)

VACUUM

Crankcase, 100% load, minimum	2 cm H_2O

PRESSURES (100% load)

Air start	10.55 kg/cm^2 (150 PSI)
Air manifold	2.11 kg/cm^2 (30 PSI)
Fuel header	3.16 kg/cm^2 (45 PSI)
Lubricating oil	5.98 kg/cm^2 (85 PSI)
Water pump out, jacket & raw – Miminum	0.141 kg/cm^2 (2 PSI)

TEMPERATURE (100% load)

Exhaust:	
Cylinders	550°C
Stack	600°C
Lubricating oil, out	85°C
Water, jacket, out	80°C

AIR FLOW

440 RPM	43 kg/hr
1100 RPM	1440 kg/hr

SHUTDOWN

Engine will shut down when:

Mechanical overspeed trips at	1260 RPM

Data subject to change without notice.

LUBRICATING OIL

INTRODUCTION

Development of high output diesel engines and the difficulty in obtaining distillate fuels with sulphur levels below 1%, adds increasing importance to the role of lubricating oils for properly protecting the dynamic components of the engine.

The oil industry, in keeping pace with these developments has developed or can develop lubricants which satisfactorily meet today's requirements.

The recommendations included in this Maintenance Instruction are offered as a guide to our customers, in selection and maintenance of engine lubricating oil.

OIL SPECIFICATION AND EVALUATION PROCEDURE

Unless the lubricant has earlier been successfully used on Bombardier manufactured engines, selection and evaluation of a suitable heavy duty lubricant should be carried out as suggested hereunder, before a lubricant is considered suitable.

Oil Supplier

A reliable oil supplier capable of making product recommendations, commensurate with Bombardier specifications and specific environmental influences, as well as having ability to furnish lubricants on a consistent quality level, should be consulted.

Oil Specification

Only an SAE 40 additive type lubricant conforming at least to API "CD" with adequate Alkalanity, (properties of a typical oil are listed below) and having been qualified through satisfactory field evaluation tests, as suggested in this M.I., should be used on Bombardier engines.

Property	Limits New Oil
Viscosity:	
SUS at 98.9°C (210°F)	72 - 85
CSt at 98.9°C (210°F)	13.5 - 16.8
SUS at 37.8°C (100°F)	700 - 1100
CSt at 37.8°C (100°F)	151 - 237.5
Viscosity Index	60 - 100
Flash Point °C	216
Pour Point °C	4.5 max.
Total Base No.	7 to 10 (if sulphur content of fuel is 0.5% to 0.7%) 10 to 13 (if sulphur content of fuel is 0.7% to 1%)

NOTE: Bombardier should be consulted for lube oil requirements if the sulphur content of fuel oil is above 1%.

Field Evaluation

Oils meeting the above specification are considered suitable for a field test. The field test should be conducted on a minimum of two Bombardier engines. The test duration should not be less than one year. The test engines should be subjected to normal service and maintenance schedule.

Data, in respect of physical and dimensional checks of the key components as listed below, should be collected before and on completion of the field test.

1. Cylinder Liner Diameter (Inside) - Fully Cleaned

   a. Location of top ring travel
   b. 6" from location (1)
   c. At bottom liner seat location

   Diameters to be measured at two right angle axes - along longitudinal and transverse directions.

2. Piston Dimensions

   a. Diameter (location crown top) - 2 axes - along axis of piston pin and at right angle
   b. Diameter (location crown bottom) - 2 axes - along axis of piston pin and at right angle
   c. Diameter (location below pin) - 2 axes - along axis of piston pin and at right angle
   d. Diameter piston pin hole - 2 locations
   e. Ring groove depth - all five grooves
   f. Piston pin diameter - 3 locations

3. Piston Rings

   a. Ring gaps - Use a new liner for measureing gap - all five rings
   b. Ring depth - all five rings

4. Dimensions of:

   a. Valve guides inside diameter
   b. Valve lever shaft and bushing diameters
   c. Fuel pump lever bushing inside diameter
   d. Fuel pump roller pin diameter

5. Crankpin Diameters (All pins)

6. Visually observe and record conditions of:

   a. Small end bushings)
   b. Big end bearings)
   c. Main bearings) Take photographs
   d. Camshaft lobes & rollers)
   e. Valves and seats)
   f. Turbocharger bearings)

7. Engine performance data for:

   a. Engine load
   b. Exhaust temperatures
   c. Lube oil pressures in the manifold
   d. Air manifold pressures
   e. Turbine inlet temperatures

The wear rate and physical condition data supplied by the customer/oil supplier will be evaluated by Bombardier.

After successful completion of the field test programme the oil will be considered satisfactory for use.

Oil formulation established and proven by the above programme should not be changed. Any change in the additives or revision of the formulation in any way must be evaluated by the above method before the oil is considered suitable for use.

NOTE: The above evaluation programme is a complete responsibility both financially and otherwise, of the oil supplier, and/or the user. Bombardier will assist in carrying out analysis of test data and act only in an advisory capacity.

Mixing of Lubricants

Bombardier's recommendation against mixing of oil types cannot be over-emphasized, however, if this becomes mandatory, following suggestions are made to assist in reducing the risk associated with this practice.

- The number of lubricating oils to be mixed must be restricted to three for a given area of operation.
- The lubricants considered for mixing should have same additive concentrate.
- After the lubricants have been selected, an equally proportioned mixture must be subjected to field evaluation test listed above, and results analysed by Bombardier before adopting this practice for the fleet operation.

MAINTENANCE/LUBRICANT CONTROL

Key to proper evaluation and control of used lubricants, for satisfactory engine performance lies in:

- Knowing the oil type, the engine and the service severity
- Developing histories of a series of tests
- Correlating analytical results with engine condition
- Watching for abrupt changes for normal used oil condition

See Table for recommended test, frequency, ASTM test method, limits and action for lubricating oil used on Bombardier engines.

RECOMMENDED TESTING AND LIMITS FOR USED OIL

TEST	RECOMMENDED FREQUENCY	ASTM TEST DESIGNATION	USED OIL LIMITS
Appearance & odor	Trip	No Numerical Limits - Interpreted by observer	
Crackle	Trip	No Numerical Limits - Interpreted by observer	
Blotter Spot Test	Trip	No Numerical Limits - Interpreted by observer	
Viscosity Increase at 100°C	Monthly	D 88 or D 445	± 20%
Viscosity Increase at 40°C	Trip	D 88 or D 445	± 30%
Viscosity Index	Monthly	D 567	
Pentane Insolubles	Monthly	D 893	3% max. (coagulated)
Benzene Insolubles	Monthly	D 893	Report
Fuel Dilution Vol. %	Trip	D 322	5% max.
Sulphated Ash Content	Monthly	D 874	6% of new value
Total Base No.	Monthly	D 2896	3 - for oils with TBN of 7 to 10 when new
Total Base No.	Monthly	D 2896	6 - for oils with TBN of 10 to 13 when new
PH	Monthly	D 664	5

TRACE ELEMENTS PPM MAX.

TEST	RECOMMENDED FREQUENCY	ASTM TEST DESIGNATION	USED OIL LIMITS	If results higher than limit inspect
Aluminium	Monthly	Spectrographic	5 PPM	Piston
Chromium	Monthly	Spectrographic	10 PPM	Liner & water leaks
Copper	Monthly	Spectrographic	20 PPM	Bushings
Iron	Monthly	Spectrographic	50 PPM	Rings and other ferrous parts
Lead	Monthly	Spectrographic	10 PPM	Main Conn. rod & turbo, lead bearing
Silicon	Monthly	Spectrographic	5 PPM	Air filters
Sodium	Monthly	Spectrographic	30 PPM	Water leaks (water treatment contains sodium)

NOTE: If any trace elements show a sudden or unexplained increase, this is sufficient reason to inspect engine components for unusual wear.

LIST OF LUBRICATING OILS KNOWN TO HAVE PERFORMED SATISFACTORILY ON 251 ENGINES

The inclusion of a product in this list does not imply approval or endorsement by Bombardier. It is published for the information of operators of 251 engines to assist them in obtaining satisfactory engine performance.

Supplier	Brand Name	TBN
BP Canada Ltd.	BP Energol 1C-RG40	6
BP Oil Company (USA)	BP Dieselube RR240	6
BP Trading Co. Ltd. (International)	BP Energol 1C-R1140	6
	BP Energol 1C-RT40	7
Gulf Oil Canada Ltd.	Ralube 950	
Gulf Oil (USA)	Gulf Oil 493	
Exxon (Imperial Oil Ltd., Canada)	Galena RD40	6.4
Exxon Corporation	Dion RDX	
Pemex (Mexico)	Dieselmex	
Shell Canada Ltd.	Tornus Oil 40	
Shell Oil Company and Affiliates	Caprinus T Oil 40	7
	Caprinus R Oil 40	10
	Tornus Oil 40	7
	Caprinus Oil 40	10
	Janus Oil 40	11
	Rotella T Oil 40	9
	Rotella TX Oil 40	9.5
Texaco Canada	DEO 1570	6.5
Texaco Inc. (USA and overseas)	2208 Taro 4-80	

FUEL OIL SPECIFICATIONS

This bulletin provides recommendations for fuel oil to provide efficient low maintenance operation of the engines, as well as economical procurement of the fuel.

The fuel shall conform to the following requirements (ASTM Test Methods).

Cetane Number	40 min.
Distillation Temperature (90% Point)	640°F max.
Flash Point	125°F min.
Water and Sediment	0.05% max.
Conradson Carbon Residue (10% Bottoms)	0.35% max.
Ash	0.01% max.
Viscosity SSU @ 100°F	32-45
Sulphur	1.8% max.
Copper Strip Corrosion	No. 3 max.

NOTES:

1. For cold weather operation, the cloud point and pour point shall be 10°F below the prevailing ambient temperature, except where fuel oil heating facilities are provided.

2. Low atmospheric temperatures, as well as engines operating at very high altitudes, may require the use of fuels with a higher cetane rating.

3. Gum content of the fuel shall be at a level consistent with satisfactory engine performance.

4. Fuel oil, lubricating oil and engine service are mutually interdependent. A marked change in any one of these variables should be accompanied by careful engine observations to determine the effect of the change on engine condition.

5. Fuels not meeting the above requirements in all respects shall only be used after testing has established their affect on engine operation and maintenance.

6. "Fuel Oil, Diesel, Marine", to military specification MIL-F-16884 meets the above requirements.

7. "Turbine Fuel", to grade JP-5 of military specification MIL-T-5624 is acceptable.

Data subject to change without notice.

*8. Fuels meeting the above requirements in all respects except for the sulfur content may be suitable for use. If the sulfur content of the fuel is over 0.75%, care should be taken to ensure the use of a lubrication oil having a total base number (TBN) that is compatible with respect to the sulfur level of the fuel. For further information, consult Alco Power Inc., Technical Publications Department.

STANDBY SERVICE UNITS

Standby units have a particular problem in that a comparably large fuel supply is required, but little is used during the weekly exercising of the engines.

All fuel oil tends to degrade during extended storage. The degradation, in general, is of two types. The first is oxidation and polymerization resulting in the formation of soluble and insoluble gums. The gums in the fuel can ultimately result in exhaust valve sticking during the unloaded idling of the engine during exercising. The second is bacteria growth at the interface of the fuel and water in the storage tank, resulting in clumps of bacteria in the fuel. This bacterial growth will result in fuel filter plugging and has been known to cause fuel injection sticking.

Both of these degradation processes can be inhibited by the use of stability additives put into the fuel. The oxidation can be limited by certain proprietary anti-oxidants and dispersants, while the bacteria can be controlled by the use of biocides. However, fuels vary in their response to both the inhibitors, and testing will be required to determine the suitable dosage of the material. Also, it is known that the oxidation inhibitor cannot provide indefinite protection against the formation of the gums, and testing of the fuel would be required periodically to establish that the gums are within allowable limits. The use of the additives, particularly the biocide, may result in a conflict with environmental air regulations in some areas.

In view of the testing and difficulties involved in assuring proper stability of fuel oil with additives, the most satisfactory method for insuring good fuel at all times is to replace the fuel periodically. We recommend that arrangements be made with the fuel supplier to pump out the fuel at six month intervals and replace it with new fuel. The pumped out fuel can be used by the supplier in less critical applications or can be dumped into a bulk storage tank thereby diluting the contaminants. It is probable that this can be accomplished at less cost than trying to maintain the fuel in good condition by treatment.

WATER TREATMENT

DESCRIPTION

In order to prevent deterioration of cooling water system components, a suitable water treatment must be used and maintained at recommended levels at all times. Three types of water treatment are considered satisfactory:

1. Chromate Type 8.5-10.5 pH
2. Boron-Nitrite Type #
3. Silicate-Nitrite Type #

Concentration determines pH Value

Only clean, soft water should be used in the cooling system. If naturally soft water is not available, condensate or softened water should be used. Under no circumstances should boiler water treatments or commercial cleaners be used which could cause corrosion, or which could attack engine cooling system gaskets, grommets or flexible connections.

Proper maintenance of the water treatment is essential for long life of the components which are in contact with the engine cooling water. The concentration of the water treatment should be checked at such periodic intervals as required to insure that the minimum requirements are met at all times. To secure maximum life and minimum maintenance expense, the engine should never be operated with the cooling water treatment below the recommended level.

The following proprietary water treatments, when properly maintained at concentrations recommended by the manufacturer, have been known to provide satisfactory protection:

Ameroid DEWT- NC	Nalco 39
Dearborn 517	Nalco 40
Dearborn 521	Nalco 2000
Dearborn 527	Nalco 2100
Dearborn 528	
Products Packaging D-24	Perolin-Bird Archer DCT-100
Drew Maxigard	

Other water treatments may be used provided that the requirements of concentration and 8.5 to 10.5 pH value are met.

All water treatments should be used according to the manufacturers recommendation, and tested with kits approved by them. The use of boron-nitrite or silicate-nitrite treatments requires greater care in maintaining the required treatment concentration than is required by the chromate treatments.

IMPORTANT

ENGINES USING ANTIFREEZE

Ethylene glycol is not compatible with chromate type water treatment (Dearborn 517, etc.). The usual antifreeze solutions do not contain sufficient corrosion inhibitor to satisfactorily inhibit the cooling system. Therefore, nonchromate type inhibitors (Dearborn 527, Nalco 39) must be added to the coolant.

Dearborn 527 or Nalco 39 nonchromate water treatment must be maintained in the cooling system of these engines at all times at a minimum concentration of 3/4 oz. treatment per gallon of coolant. The water treatment should be added in the required quantity at initial fill, and a proportional amount to any make-up water or antifreeze. The concentration of water treatment should be checked monthly, as recommended by the supplier of the water treatment. Chromate type water treatment (Dearborn 517, etc.) must not be used in engines that use ethylene glycol or propylene glycol in the coolant.

WARNING

ENVIRONMENTAL REGULATIONS LIMIT THE DUMPING OF CHROMATE TREATMENTS. CONSULT THE LOCAL ENVIRONMENTAL AGENCIES FOR APPLICABLE REGULATIONS.

Data subject to change without notice.

RTV SILICONE SEALANT

GENERAL PROCEDURE FOR SEALING JOINTS WITH SILICONE RUBBER SEALANT

DESCRIPTION

This specification covers a general procedure to be followed when sealing bolted flange type joints with silicone rubber sealant.

APPLICATION PROCEDURE:

1. Clean mating surface with a good evaporating solvent.

2. Apply sealant, Alco Cat. No. 21559343. Nominal bead size is 1/8"; maximum permissable is 1/4". Hold nozzle 1" to 2" above part when applying (if possible).

3. Sealant should circle all bolt holes and dowel holes. In general, center bead on flange surface.

4. Parts must be assembled within 20 minutes after starting to apply sealant.

5. Bolts must be torqued to final value within 12 hours of applying sealant.

6. Any excess sealant which squeezes from the joint should be allowed to cure. Cut cured excess from the parts with a knife.

7. Personnel handling silicone rubber sealant should avoid touching surfaces which are to be painted as paint will not stick to silicone.

8. Avoid smearing sealant as this will decrease cure times and may damage seal.

PROCEDURE FOR SEALING CYLINDER BLOCK TO THE ENGINE BASE JOINT WITH SILICONE RUBBER SEALANT

DESCRIPTION

This specification covers the procedure to be followed for sealing the engine cylinder block to base joint using silicone rubber sealant.

APPLICATION PROCEDURE:

1. Clean mating surfaces with a good evaporating solvent.

2. Apply sealant, Alco Cat. No. 21559343. Nominal bead size is 1/8"; maximum permissable is 1/4". Hold nozzle 1" to 2" above base when applying.

3. The base to block joint is to be sealed with a pattern like that shown in Fig. A below.

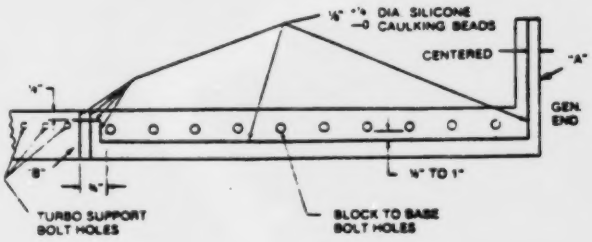


Figure A

4. Apply as follows:

   a) Start at flywheel/generator end. Apply one bead in center of end plate mating surface.

   b) Continue down the length of the base to just past the last clearance hole. Bead should be 1/2" to 1" from the outside edge of clearance holes.

   c) Turn 90° and run bead to 1/2" from the inside edge of rail.

   d) Turn 90° and apply bead along rail 1/2" from edge to a point just even with the first turbo support bolt hole.

   e) Apply 2 beads which cross rail between first turbo support bolt hole (from generator end) and last block to base bolt hole.

5. The block must be set on the base within 20 minutes after starting to apply the sealer.

6. Alignment, doweling and bolting of the block to base must be completed within 12 hours of applying the sealer.

7. Any excess sealer which squeezes from the joint should be allowed to cure. Cut cured excess from the parts with a knife. Excess sealer must be evident at areas "A" and "B" after block is mounted to base.

8. Personnel handling silicone rubber sealant should avoid touching surfaces which are to be painted as paint will not stick to silicone.

9. Do not smear sealant after applying as this will decrease cure times and void this procedure.

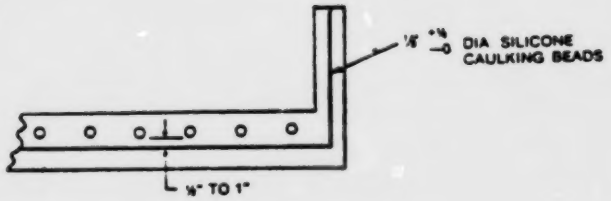


Figure B-1

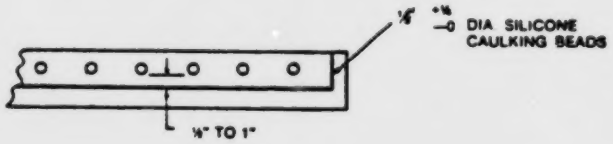


Figure B-2

NOTE: Be sure to apply sealant across mating end of generator end shim.

PROCEDURE FOR SEALING CYLINDER BLOCK TO THE ENGINE BASE JOINT WITH SILICONE RUBBER SEALANT WHEN BASE AND BLOCK SHIMS ARE USED

DESCRIPTION

This specification covers the procedure to be followed for sealing the engine cylinder block to base joint using silicone rubber sealant when base and/or block salvage shims are required.

APPLICATION PROCEDURE:

1. Clean mating surfaces with a good evaporating solvent.

2. Apply sealant, Alco Cat. No. 21559343. Nominal bead size is 1/8"; maximum permissable is 1/4". Hold nozzle 1" to 2" above base when applying.

3. Apply sealant to flywheel/generator end of base and/or block per Fig. B-1 and Fig. B-2 below:

4. Apply generator end shim with positioning screws, Alco Cat. No. 21529633.

5. Apply sealant to free end half of base and/or block per Fig. C-1 and C-2 below:

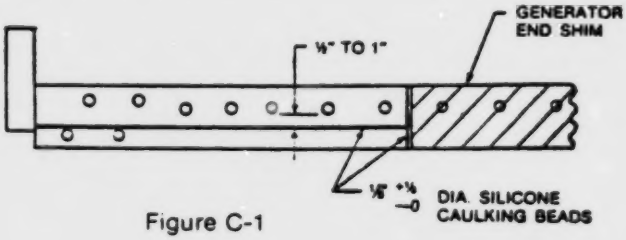


Figure C-1

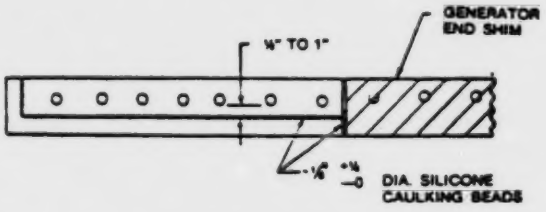


Figure C-2

6. Apply free end shim with positioning screws, Alco Cat. No. 21529633.

7A. When block shims are used repeat procedure for other side of base.

7B. When base shims are used, apply sealant to free end plate mating surface per Fig. D below:

NOTE: Be sure to apply sealant across mating end of free end shim.

8. When base shims are used, apply "Top of free end plate" shim with positioning screw, Alco Cat. No. 21529633.

9. When base shims are used, repeat procedure for other side of base.

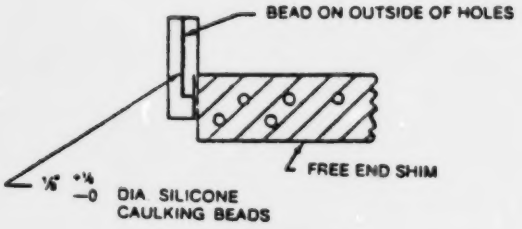


Figure D

APPLICATION RESTRAINTS:

1. The shim must be set on the base or block within 20 minutes after starting to apply the sealant.

2. After applying the shim with sealant to the cylinder block or engine base, application of the block to base sealant and the cylinder block to the engine base must be initiated within 2 hours.

3. When base shims are used, the shims in the area of the turbo support should be firmly bolted with appropriate capscrews until the turbo support is applied.

4. Any excess sealant which squeezes from the joint should be allowed to cure. Cut cured excess from the parts with a knife.

5. Personnel handling silicone rubber sealant should avoid touching surfaces which are to be painted, as paint will not stick to silicone.

6. Do not smear sealant after applying as this will decrease cure times and void this procedure.

PERMISSABLE ALTERNATE SEALANTS

If the sealant listed in the procedures sections of this maintenance instruction are not available, then the following may be used as an alternative.

1. GE RTV 103-Black Silicone Rubber Sealant.

2. Bulk RTV Silicone Rubber Sealant; Alco Cat. No. 21559332, in 5 gallon pail.

3. GE RTV 102-White Silicone Rubber Sealant; Alco Cat. No. 21559331, in 120Z cartridge.

CYLINDER LINER

DESCRIPTION

Cylinder liners fit in the cylinder block with a metal-to-metal fit. Each liner has a collar on its upper end which seats in a counterbore in the cylinder block. One seal ring in a groove near the top of the liner and two seal rings in grooves near the bottom of the liner, seal the fits between the liner and cylinder block.

Metal-to-metal joints of the flat lap type form the compression seal between the liners and cylinder heads.

REMOVAL

Jack liner free and remove from cylinder block using special cylinder liner removal tool.

INSPECTION AND MAINTENANCE

When a piston is pulled, the liner should be carefully inspected for scores and deep scratches. Remove the ridge formed in the upper bore, by the top compression ring, with a ridge removal tool. Measure the liner bore at several points just below the ridge formed at the upper end of the top piston ring travel holding the micrometer parallel to the surface of the block and perpendicular to the centerline of the engine.

The exterior surface of the liner (the cooling water surface) should be inspected for corrosion. Shallow, wide pits in which the width of the pitted cavity is from two to six times its depth can occur either as a general or local condition and still be harmless unless they effectively destroy the external surface of the liner. Relatively narrow, deep crevices are considered harmful; these are characterized by pits in which the depth is from one to several times the width of the pit and in some cases have even penetrated to the bore. If these pits can be probed and found to be more than superficial, over 3/32" deep, the liner should be rejected as the crevices of pits will progress rapidly resulting in failure.

Pits deemed harmless may be covered with Cast Iron Cement ("Smooth-On" or equivalent) and the liner reused.

Manufactured by Smooth-On Manufacturing Co., Jersey City, New Jersey.

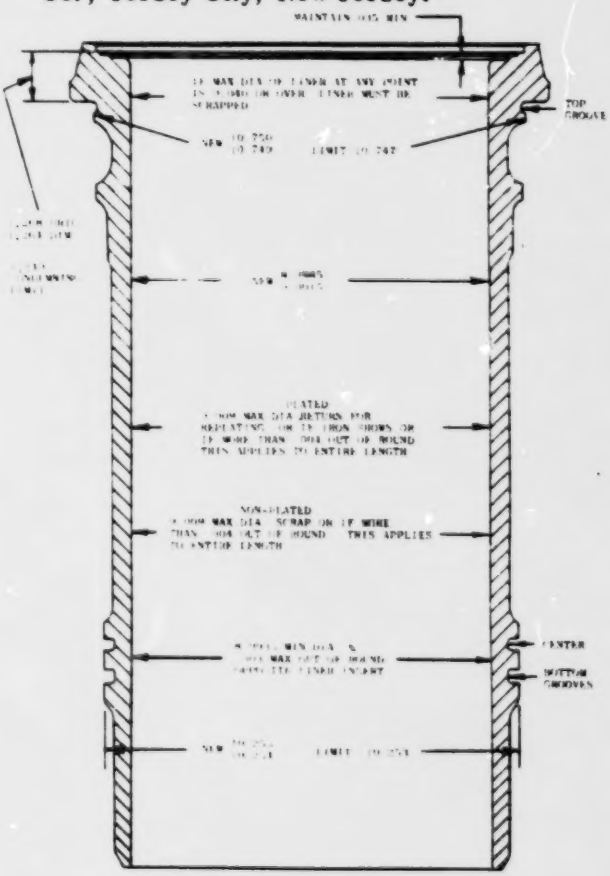


*FIG. 1 - PHOTO 2677
LINER WEAR LIMITS

The compression seal joint on top of the liner should be checked and, if a full bearing surface cannot be produced, the seat must be lapped with a lapping tool. Two tools are required. One should be retained for checking purposes and the other for lapping.

Sealing surface must be smooth and in one plane. Check with bluing. A continuous blue mark should show not less than 1/16" wide all around. See Fig. 1 for liner wear limits.

INSTALLATION

Before installing a liner, first clean off any roughness on the liner fits (see "Cylinder Block" publication) in the cylinder block to prevent possible tearing and rolling of the liner seal rings as they enter these fits.

NOTE: The minimum interference at the lower liner fit must be 0.0005", whether or not a sleeve is used; therefore, it may be necessary to apply cylinder liners selectively to certain bores.

*Install the white colored seal, Catalog 2151452, in the top ring groove, Fig. 1. Install the brown or black colored ring seal in the center ring groove. NOTE: The black colored ring seal will have Catalog No. 2151456 and the word "Viton" molded on it. Install the black colored ring seal, Catalog No. 2151455-1 in the bottom ring groove.

Apply lubriplate to the bottom liner seal rings and fit and to the block fit. Lower the liner into the cylinder bore. Position the liner so that the marking "Fuel Pump Side" (or "FPS") is on the centerline of the fuel pump. As the liner seal rings enter the lower fit, pressure will have to be applied to force the liner down. To do this, either reverse the liner puller tool or pry the liner down using blocks and a pry bar.

CAUTION: Avoid twisting the liner seal rings when applying them to the liner. The life of a seal ring is greatly shortened when twisted. If the rings should become twisted during application to the liner, straighten them before the liner is lowered in the cylinder bore.

OPERATION OF RIDGE REMOVER GRINDER

1. Clean all carbon from area of ridge with solvent.

2. Install grinding drum and spacer from adapter kit to ridge remover output shaft. Spacer goes on output shaft before washers and grinding drum.

3. Install abrasive sleeve on grinding drum. To change abrasive sleeve, loosen grinding drum by holding output shaft on top with a wrench and turn nut on output shaft counterclockwise. Remove old abrasive sleeve. Install new sleeve squarely on grinding drum. Tighten nut firmly against grinding drum. Tighten grinding drum until abrasive sleeve has a slightly rounded surface.

4. Install locating adapters from adapter kit to ridge remover.

5. Install spacer on each positioning arm shaft. When installing or removing spacers on positioning arm:

   a. Unscrew stop bars (horizontal piece from the positioning arms.
   b. Push positioning arm shafts out bottom of housing.
   c. Install or remove spacers from each positioning arm shaft.
   d. Replace positioning arm shafts and stop bars.

6. Push ridge remover head down and tighten spindle lock screw in notch of dowel pin guide.

7. Clean locating adapters.

8. Place positioning arms in an outward position and gently slip the ridge remover into the cylinder liner until the positioning arm stop bars contact the top of the liner. The ridge remover is properly positioned when the positioning arms are fully extended.

9. Firmly lock ridge remover in place by turning the T-handle wrench in Allen set-screws above positioning cam.

10. Rotate positioning arms in toward ridge remover and drop them into notches of housing.

11. Adjust follower arm until grinding sleeve touches cylinder liner wall.

12. Mount on the ridge remover spindle any portable electric or air drill motor which has a speed of 275 to 400 RPM. The spindle is sized for a standard 1/2" drill chuck.

13. When removing ridges from liners, grinding head must always be locked in down position to prevent up and down motion of grinding drum.

14. To change belts, lock grinding head in down position. Tap up on spindle shaft and separate the gears enough to change belts.

TOOLS

Item	Cat. No.
Puller Assembly	2470412
Grinder, Ridge Removal	2470262-1
Belts	2471262
Sleeves, Abrasive	2471263
Kit, Adapter	2471266
Wrench, T-Handle	2471264
Wrench, L-Handle	2471265
Ring - For checking distortion of cylinder heads and for checking and lapping cylinder head and liner seats	2471422
Ring - For checking and lapping liner to cylinder block seat	2471423
Lifter	2470703

INSPECTION, GEAR TEETH

PITTING

Light pitting scattered over the entire surface or at the base of the gear teeth, shown in Photo 4221, is a common condition and need not cause undue alarm.

Gears should be scrapped if the working surface of the teeth is severely damaged by pitting or spalling to a degree shown in Photo 4220.

Photo 4220 shows a particular form of failure in that the damaged area is on one side of the teeth only, thereby indicating serious misalignment and calling for careful inspection of the supporting structures. When installing a replacement gear after this type of failure, the gear contact should be checked by bluing one of the two mating gears. The contact area must be near the center of the gear; it will be short since all gear trains include crowned gears to minimize the effects of misalignment.

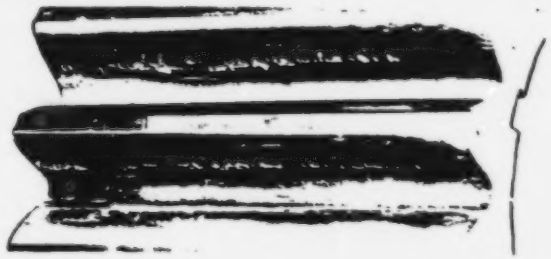


PHOTO 4221 - LIGHT PITTING AT BASE OF GEAR TEETH

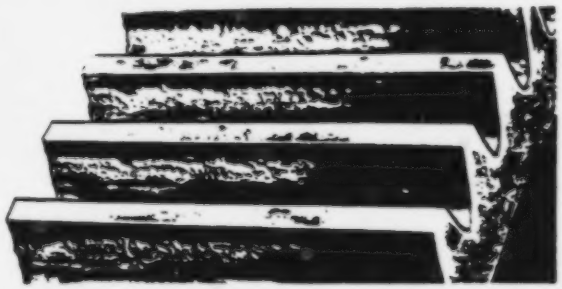


PHOTO 4220 - GEAR TEETH SEVERELY DAMAGED BY PITTING OR SPALLING

SCUFFING

Light scuffing, shown in Photo 4219 and characterized by vertical root to tip lines, is an indication of faulty lubrication calling for review of oil filter maintenance practice and inspection of the oil spray nozzles. There are three nozzles, one at the front end casing lubricating the pump gears, and one each in the two camshaft gear covers.

The scuffing may have resulted in raising sharp feathers edges at the tip of the teeth; these should be removed with a file before reapplication of the gear.

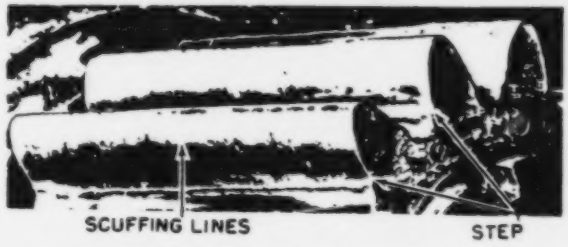


PHOTO 4219 - WORN GEAR SHOWING STEP SCUFFING LINES ON TEETH

FATIGUE BREAKAGE

Gears with broken teeth should be scrapped. See Photo 4218. Fatigue cracks discovered by visual, magnaflux, or other similar means, as illustrated in Photo 4217, are the beginning of a failure. Such gears should be scrapped.

PHOTO 4218 - GEAR WITH TOOTH BROKEN OFF AT END

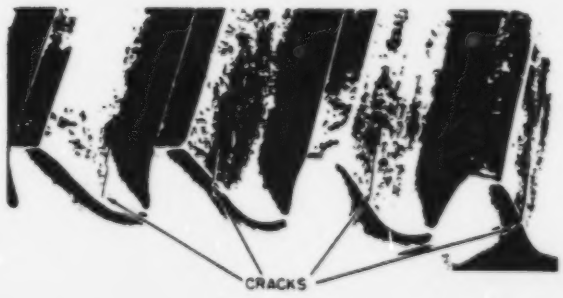


PHOTO 4217 - GEAR WITH FATIGUE CRACKS AT END OF TEETH

Data subject to change without notice.

MODEL DIFFERENCE SHEET

ENGINE OVERSPEED TRIP

The purpose of this Model Difference Sheet is to identify procedures that differ from those shown in your Maintenance Instruction.

Please retain this MDS with MI-11059C.

CHANGE CLEARANCES ON PAGE 4 TO READ:

CLEARANCES:

Trip Lever Arm to Upper Housing	0.004 - 0.012 in. dia. cl.
Trip Lever Arm to Reset Shaft	0.001 - 0.004 in. dia. cl.

CHANGE PARAGRAPH 3 ON PAGE 6 TO READ:

3. Screw spring retainer *out* to increase shutdown RPM and *in* to decrease shutdown RPM.

Data subject to change without notice.

ENGINE OVERSPEED TRIP

DESCRIPTION

The engine is equipped with an automatic overspeed stopping device, Fig. 1 consisting of a spring loaded plunger (25) which, during normal operation, is held within the carrier (24). However, when the centrifugal force is great enough to overcome the spring force (an overspeed condition) the plunger is instantly thrown outward.

In the outward position, the plunger strikes a trip lever (30), releasing the spring loaded reset shaft (7). This shaft is directly coupled to the fuel pump control shaft (2). As the spring (4) unwinds, it causes rotation of the fuel pump control shaft which moves the fuel pump racks to shut-off position. An overtravel mechanism at the governor end allows the overspeed device to return the racks to "Off" even though the governor may remain at full fuel.

Accessories such as the vibration damper or flywheel may be attached between the carrier assembly and the camshaft to help eliminate camshaft vibrations.

In some applications a microswitch (46) is mounted on a plate attached to the overspeed trip upper housing (3). This switch is operated by a cam attached to the reset shaft (7) and gives either an audible or a visual indication that the overspeed has tripped.

To reset, pull the reset handle (8) until it latches. This rewinds the torsion spring (4) and resets the trip lever (30).

To trip manually, pull the emergency shutdown handle (12) in the direction of the arrow shown on the lower housing cover (18).

DISASSEMBLY

LOWER HOUSING TRIP ASSEMBLY

Trip mechanism manually by pulling trip lever handle (12) in direction of arrow.

With Carrier Only

The trip assembly is built as a separate unit and is installed in a carrier (24) which is bolted to the free end of the camshaft (23). Fig. 1. It also serves as a thrust face for the camshaft.

CAUTION: Do not run the engine with carrier removed.

With Vibration Damper

Refer to Insert, Fig. 1.

The trip assembly is built as a separate unit and is installed in a carrier (24) which is attached to the camshaft vibration damper. The carrier and vibration damper are then attached to the free end of the camshaft.

1. Remove lower housing cover (18). Note direction of arrow for reassembly.

2. Remove lockwired capscrews (33) and lockplate (13) which secure carrier (24) and damper to camshaft (23).

3. Remove carrier (24) and vibration damper assembly. Two capscrew holes in carrier are tapped for insertion of puller screws to facilitate removal.

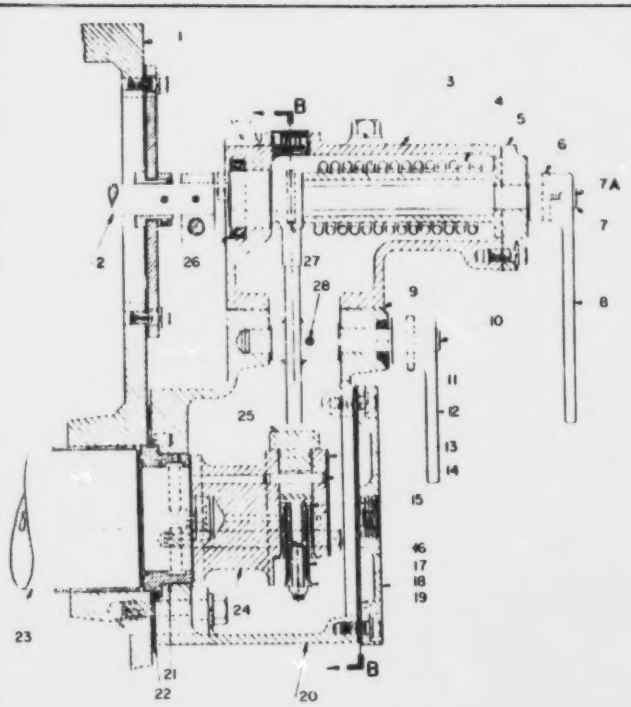
With Flywheel

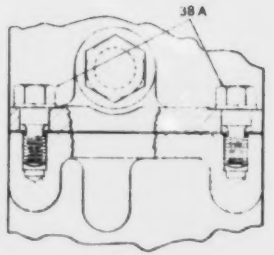
Refer to Insert, Fig. 1.

The trip assembly is built as a separate unit and is installed in a carrier (24) which is attached to the flywheel (45). The carrier and flywheel are then attached to the camshaft.

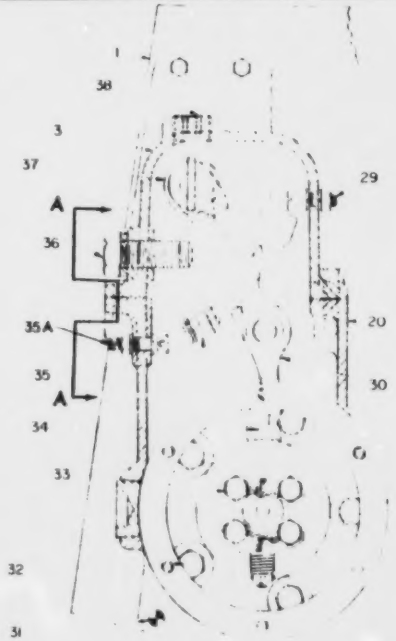
1. Remove lower housing cover (18). Note direction of arrow for reassembly.

2. Remove lockwired capscrews (33) which secure lockplate (13), carrier (24), and flywheel (45) to camshaft (23).

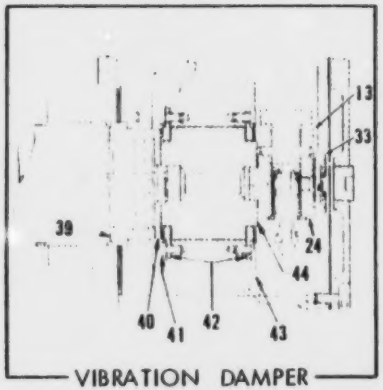




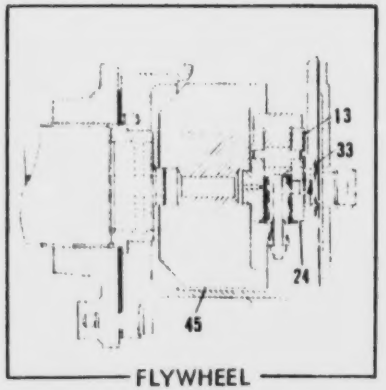
SECTION A-A



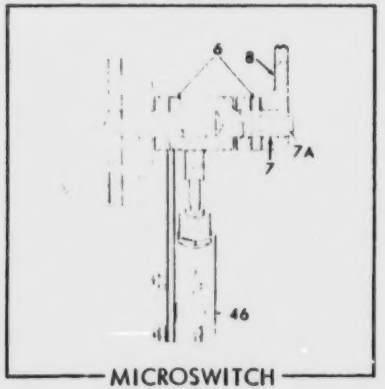
SECTION B-B



VIBRATION DAMPER
(If Used)



FLYWHEEL
(If Used)



MICROSWITCH
(If Used)

1. Cylinder Block
2. Fuel Pump Control Shaft
3. Upper Housing
4. Torsion Spring
5. Spring Cover
6. Dowel
7. Reset Shaft
7A. Setscrew, Pin to Shaft
8. Reset Handle
9. Gasket, Upper to Lower Housing
10. Trip Lever Shaft
11. Oil Seal
12. Trip Handle
13. Lockplate
14. Dowel Stop
15. Spring Seat
16. Spring
17. Spring Retainer
18. Lower Housing Cover
19. Gasket, Cover to Lower Housing
20. Lower Housing
21. Camshaft Thrust Bearing
22. Gasket and Shims, Lower Housing to Cylinder Block
23. Camshaft
24. Carrier
25. Plunger
26. Oil Seal
27. Split Taper Pin
28. Dowel
29. Stop Screw
30. Trip Lever
31. Locating Dowel
32. Capscrews, Lower Housing to Cylinder Block
33. Capscrews, Trip Assembly
34. Bearing Location Dowel
35. Trip Latch Spring
35A. Spring Screw
36. Stop Screw
37. Trip Lever Arm
38. Plug
38A. Special Capscrew

VIBRATION DAMPER (If Used)

39. Thrust Bearing
40. Thrust Plate
41. Lockwired Capscrew
42. Retainer
43. Outer Ring
44. Spider

FLYWHEEL (If Used)

45. Flywheel

MICROSWITCH (If Used)

46. Microswitch

FIG. 1 - PHOTOS 8100, 8101, 8102, 8690, 8696
ENGINE OVERSPEED TRIP

3. Remove lockplate (13), carrier (24), and flywheel (45) from camshaft (23).

CARRIER ASSEMBLY

Refer to Fig. 1.

1. Remove locknut from plunger (25).

2. Remove spring retainer (17), spring (16) and spring seat (15).

3. Remove dowel stop (14) and plunger (25).

UPPER HOUSING

Refer to Fig. 1.

1. Trip overspeed mechanism manually by pulling trip lever handle (12) in direction of arrow.

2. Remove housing holddown capscrews.

3. Remove upper housing (3) and housing gasket (9).

4. Back off setscrew (7A), remove dowel (6) and reset handle (8) from shaft (7).

5. Insert a length of 1/2" dia. rod into the radial hole drilled in the spring cover (5) and use rod as a bar to prevent the spring (4) and cover (5) turning while capscrews are removed. Remove capscrews and lockwashers from spring cover (5).

6. Remove spring cover (5). It is not necessary to remove spacer between cover and upper housing (3) if one is used.

7. Remove torsion spring (4).

8. Remove plug (38) from top of upper housing (3), stop screw (36) and remove taper pin (27) holding trip lever arm (37) to reset shaft (7).

9. Remove reset shaft (7) and trip lever arm (37) from upper housing.

10. Remove oil seal (26).

LOWER HOUSING

1. Remove dowel (28) holding trip lever (30) to shaft (10).

2. Loosen trip lever spring screw (35A), unfasten spring (35) from spring screw (35A) and trip lever (30).

3. Remove trip lever spring screw (35A).

4. Pull trip lever handle (8) outward removing trip lever (30) and shaft (10) from lower housing.

5. Remove oil seal (11).

INSPECTION AND MAINTENANCE

Thoroughly clean all parts and inspect for damage, wear and broken springs. Renew gaskets and oil seals if necessary.

CLEARANCES

Plunger to Carrier----------0.003-0.005" Dia. Cl.

Spring Seat----------Metal-to-Metal to Clearance Fit of 0.002"

Trip Lever Arm to Upper Housing----------0.006-0.012" Dia. Cl.

Trip Lever Arm to Reset Shaft---------- 0.000-0.004" Dia. Cl.

REASSEMBLY

CARRIER

1. Slide plunger (25) into carrier (24) and install dowel stop (14).

2. Insert spring seat (15) and spring (16) into carrier (24) and secure using spring retainer (17) and locknut.

3. Adjust spring retainer and locknut until bottom face of locknut is 3/16" above end of plunger.

LOWER HOUSING

NOTE: If either vibration damper or flywheel are used, install with carrier during next step.

1. Install carrier (24) (and accessory, if used) on end of camshaft (23). Set lockplate (13) in position on end of carrier and secure using four capscrews (33). Lockwire (See Fig. 2).

2. Install gasket (19) and lower housing cover (18), correctly positioning arrow on cover and apply capscrews.

3. Replace oil seal (11).

4. Install trip lever (30) on trip lever shaft (10) and secure using dowel (28).

5. Hook trip lever spring (35) into hole in trip lever (30).

6. Hook other end of trip lever spring (35) into trip lever spring screw (35A) and secure spring screw to lower housing.

UPPER HOUSING

Refer to Fig. 1.

1. Replace oil seal (26) and install and lock stop screw (29) if it was removed. This stop prevents trip lever and trip lever arm from overtraveling when resetting.

2. Insert trip lever arm (37) into upper housing (3).

3. Insert reset shaft (7) and pin trip lever arm to shaft using taper pin (27), tighten setscrew (7A) and install stopscrew (36).

4. Insert one end of torsion spring (4) into hole in trip lever arm (37).

5. Insert other end of torsion spring into hole in spring cover (5).

6. Push cover (5) into bore of spacer.

7. Insert a length of 1/2" dia. rod into the radial hole drilled in the spring cover (5) and use rod as a bar to turn spring cover clockwise. Tighten torsion spring (4) until flats on cover and housing coincide. This operation requires a turn of approximately 120 degrees.

8. Holding spring tension with rod, apply capscrews to spring cover (5).

9. Install reset handle (8) in the down position for "INLINE" engines and in the up position for "V" engines, securing using dowel (6) and setscrew (7A).

10. Install gasket (9) on lower housing and position upper housing on lower housing. Apply special capscrews (38A) for alignment, then install and tighten other housing holddown capscrews, securing upper to lower housing.

ADJUSTMENTS

RESET SHAFT

The end of the overspeed shaft (7) is machined as a one tooth dog. This dog engages a similar dog clamped and doweled to the right side fuel pump con-

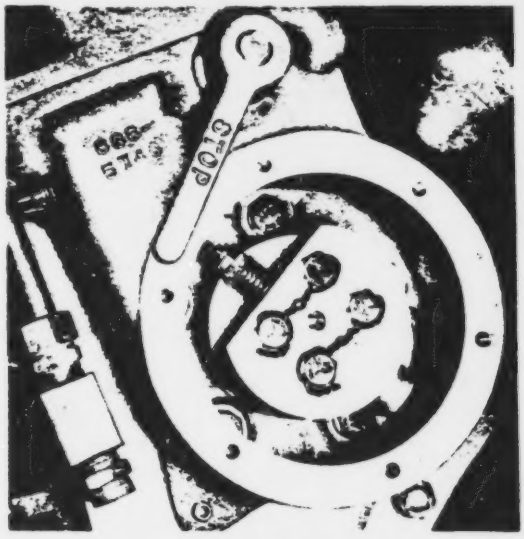


FIG. 2 - PHOTO 2955
TRIP ASSEMBLY INSTALLED

trol shaft (2). The position in which the dog is clamped and doweled must be such as to avoid any interference with the normal governor action on the fuel pump control shaft. Also, the dog must rotate the control shaft to give 0 to 2 mm rack travel when the overspeed is tripped.

TRIP ASSEMBLY

After the engine is placed in operation check the speed at which the overspeed trip shuts down the engine. If the engine does not shut down at the correct engine rpm, an adjustment is necessary. For correct engine shutdown rpm, refer to "Data Sheet" publication for Commercial engine applications or to "Tests and Adjustments - Locomotive" publication.

Engine shutdown speed is adjusted by varying the spring tension on the plunger. To make this adjustment, proceed as follows:

1. With engine stopped, remove lower housing cover (See Fig. 2).

2. Bar engine crankshaft until trip assembly is visible.

3. Screw spring retainer in to increase shutdown rpm and out to decrease shutdown rpm.

4. Replace end cover.

5. Start engine and recheck speed at which overspeed device trips. If necessary, again remove housing cover and readjust retainer spring tension.

6. Replace end cover after final adjustment.

ENGINE TURNING ARRANGEMENT

DESCRIPTION

The engine turning arrangement consists of an engine barring device, air starting motor(s), a timing pointer and a ring gear.

Figure 1 illustrates a general view of the flywheel end of the engine. It shows the location of the ring gear (2), the engine barring device pinion (1), the air starting motor pinion (4) and the engine timing pointer (3).

Figure 2 illustrates the mounting arrangement of the engine air starting motor in relation to the ring gear. For details on the air starting motor refer to the "Air Starting Motor" publication listed in the index.

The engine crankshaft may be turned when the engine is shut down by the barring device which may be operated either manually or by a portable air motor when the barring device is engaged with the ring gear.

The engine is started by the air starting motor when the motor is engaged with the ring gear. The motor operates on a maximum air pressure of 150 PSI.

The timing pointer indicates either piston top dead center or the point of fuel injection when the cylinder markings on the ring gear are correctly positioned to coincide with the markings on the timing pointer.

ENGINE BARRING DEVICE

The barring device (Fig. 3) consists of a pinion (6) and a hex head drive shaft (12) mounted in a housing (8) containing an eccentric sleeve arrangement for engaging the pinion (6) with the ring gear (5). A suitable bracket (7) mounts the barring device at the end of the engine base.

The pinion (6) is normally disengaged from the ring gear (5) and is secured in this position by a spring loaded locking pin (4).

SAFETY INTERLOCK (if used)

A cam operated pilot air valve, controlled by the barring device, prevents the engine from being started by shutting off the air supply to the air starting motor when the barring device is engaged.

A cam operated microswitch, also controlled by the barring device, may be utilized to provide a visual indication of the barring device position in the form of red or green lights on the remote control panel.

To Engage Barring Device (refer to Fig. 3)

1. Disengage locking pin (4) from hex head drive shaft by pulling locking pin up and holding it in this position.

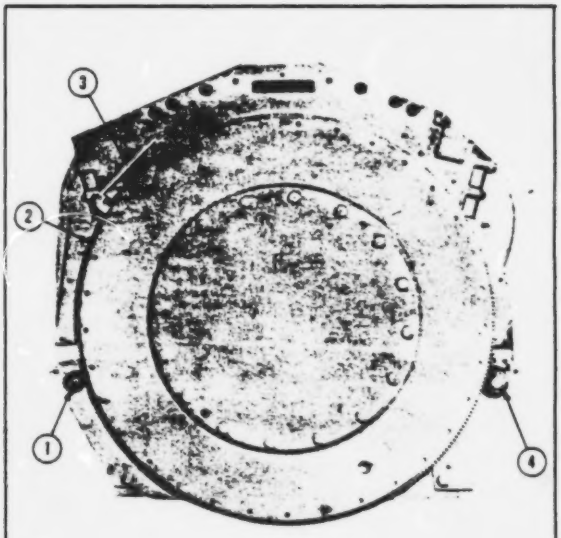
2. Move handle (9) up from its lowest to highest position and allow locking pin to drop into place. This operation engages the pinion with the ring gear and locks the barring device in engaged position.

– NOTE –

Should the handle jam between its lowest and highest position, the pinion and ring gear teeth are not in line for meshing. Lower the handle slightly until hex head drive shaft (12) can be turned to position pinion for meshing with ring gear. When the pinion is properly located, the handle will move up freely and locking pin (4) will drop to lock the hex head drive shaft in the engaged position.

To Disengage Barring Device

Unlock device by pulling up on locking pin and moving handle to extreme lower position, allowing locking pin to drop into place.

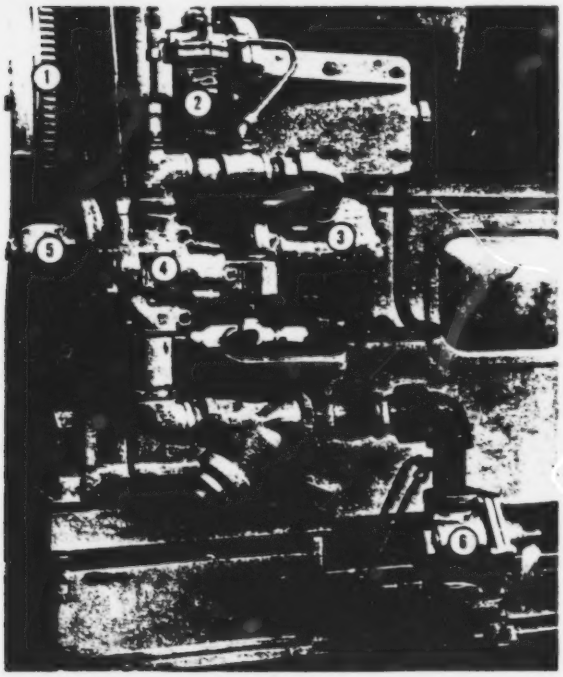


1-Engine barring device pinion 3-Timing pointer
2-Ring gear 4-Air starting motor pinion

FIGURE 1 – GENERAL VIEW FLYWHEEL END OF ENGINE

REMOVAL AND DISASSEMBLY (refer to Fig. 4)

1. Disconnect tubing from pilot air valve (if used).
2. Disconnect wiring from microswitch (if used).
3. Loosen bolts holding mounting bracket to engine base and remove the mounting bracket, barring device, pilot air valve and microswitch as an assembly.
4. Remove pilot air valve and bracket (if used).
5. Remove microswitch and bracket (if used).
6. Remove spirol pin (8), collar (7), pinion (5) and key (6) from hex head drive shaft (13).
7. Remove capscrews and lockwashers (10) holding housing (3) to mounting bracket (4). Remove bracket.
8. Move handle (11) until pin (12) securing handle is exposed in slot of housing. Drive out pin and unscrew handle.
9. Lift locking pin (2) and withdraw hex head drive shaft (13) and collar (20) from eccentric sleeve (9).



1-Ring gear
2-Air motor lubricator
3-Air motor
4-Starting air solenoid valve
5-Bendix drive
6-Air pressure reducing valve

FIGURE 2 – AIR STARTING MOTOR

– NOTE –

If pilot air valve or microswitch are not used, disregard step 10.

10. Remove pilot air valve cam (14) and microswitch cam (15). These cams are located on, and secured to, the eccentric sleeve by two spirol pins.
11. Lift locking pin (2) and withdraw eccentric sleeve (9) from housing (3).
12. If repair deems necessary, chip spot welds from spring retainer (18) and remove locking pin (2) and spring (17).
13. Drive out spirol pin (19) and remove locking pin knob (1). Remove spring retainer and spring from locking pin.

MAINTENANCE

Clean and thoroughly inspect all parts. Examine key and shaft keyway, being sure that key is tight in the shaft and no burrs exist. Inspect pinion for pitting, broken or chipped teeth and excessive wear. Inspect cam surfaces for smoothness.

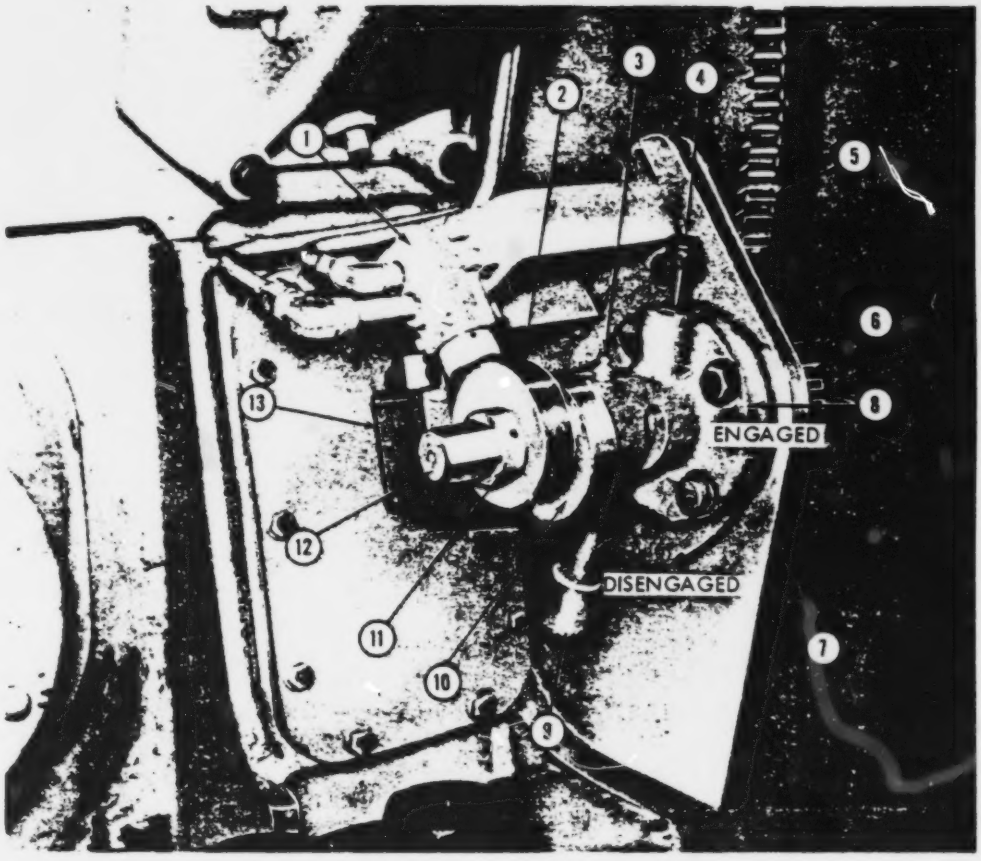
REASSEMBLY AND INSTALLATION (refer to Fig. 4)

1. Assembly housing (3) to mounting bracket (4) and apply two dowels and four capscrews and lockwashers (10).
2. Slide eccentric sleeve (9) into housing. For clearance between housing and sleeve, refer to "B", Fig. 4.
3. If used, install microswitch cam (15) and pilot air valve cam (14) on eccentric sleeve and apply spirol pins.

– NOTE –

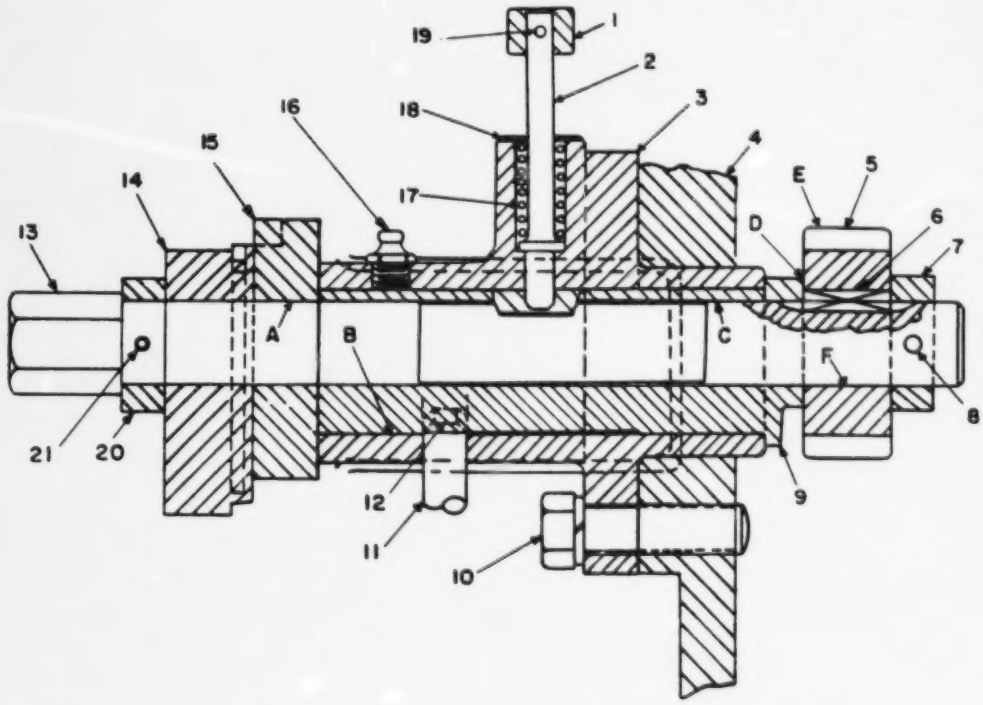
The microswitch cam (15) is the thinner of the two cams and is assembled next to the eccentric sleeve (9). The thicker, or pilot air valve cam (14) is then mated to the microswitch cam using spirol pins.

4. Assemble shaft (13), with collar (20), to eccentric sleeve. For clearance between shaft and sleeve, refer to "C", Fig. 4.
5. If removed, install spring (17) on locking pin (2) and insert assembly into housing. Place spring retainer (18) over locking pin and tack weld to housing. Apply knob (1) on locking pin and secure with spirol pin (19).



1-Pilot air valve (if used)
2-Pilot air valve cam (if used)
3-Grease fitting
4-Shaft locking pin
5-Ring gear
6-Pinion
7-Mounting bracket
8-Housing
9-Handle
10-Microswitch cam (if used)
11-Collar
12-Hex head drive shaft
13-Microswitch (if used)

FIGURE 3 – ENGINE BARRING DEVICE (with pilot air valve and microswitch)



NOMENCLATURE

1-Locking pin knob
2-Locking pin
3-Housing
4-Mounting bracket
5-Pinion
6-Key
7-Collar
8-Spirol pin, collar to shaft (pinion end)
9-Eccentric sleeve
10-Mounting capscrews and lockwashers
11-Handle
12-Taper pin
13-Hex head drive shaft
14-Pilot air valve cam
15-Microswitch cam
16-Grease fitting
17-Locking pin spring
18-Spring retainer
19-Spirol pin, knob to locking pin
20-Collar
21-Spirol pin, collar to shaft (hex head end)

CLEARANCES
(all dimensions in inches)

A - Cam and shaft . . . . . 0.018 - 0.419mm (0.0007 - 0.0165") dia.cl.
B - Housing and sleeve . . . . . 0.025 - 0.127mm (0.001 - 0.005") dia.cl.
C - Shaft and sleeve . . . . . 0.025 - 0.089mm (0.0010 - 0.0035") dia.cl.
D - Sleeve and pinion . . . . . 0.40mm (1/64") long. cl.
E - Pinion and ring gear . . . . . 0.38 - 0.99mm (0.015 - 0.035") backlash
F - Pinion and shaft . . . . . 0.000 - 0.038mm (0.0000 - 0.0015") dia.cl.

FIGURE 4 – CROSS SECTION – ENGINE BARRING DEVICE (with pilot air valve and microswitch cams)

6. Install key (6) in shaft and apply pinion (5). For clearance between eccentric sleeve and pinion, refer to "D", Fig. 4. For clearance between pinion and shaft, refer to "F", Fig. 4.

7. Apply collar (7) to shaft and secure with spirol pin (8).

8. Install handle (11) to eccentric sleeve and apply taper pin (12).

9. Mount barring device on engine base and apply original dowels and capscrews. For backlash between pinion and ring gear refer to "E", Fig. 4. If necessary to reposition barring device to obtain this backlash, redowel.

10. Lubricate with Type 10 (see "Lubricant Specifications" publication) grease through fitting (16).

11. If used, apply microswitch bracket and microswitch to mounting bracket. With barring device in the disengaged position the microswitch cam should depress the actuating roller of the microswitch 3.18mm (1/8") from its free position. Move barring device to the engaged position and check travel of the actuating roller. Total travel should be 11.11mm (7/16") from the free position or 7.94mm (5/16") from the preloaded position. Reconnect wiring to microswitch.

12. If used, apply pilot air valve bracket and pilot air valve to mounting bracket. With barring device in the disengaged position, the pilot air valve cam should depress actuating head of valve 3.98±0.79mm (5/32±1/32"). With barring device in the engaged position, check for clearance between cam and head of valve. Reconnect tubing to valve.

*RING GEAR

The ring gear is attached to the engine side of the flywheel and is marked as follows:

6 Cylinder In-Line Engine

1-6, 3-4, 2-5.

8 Cylinder "V" Type Engine

1R-4R, 1L-4L, 2R-3R, 2L-3L.

12 Cylinder "V" Type Engine

1R-6R, 1L-6L, 3R-4R, 3L-4L, 2R-5R, 2L-5L.

16 Cylinder "V" Type Engine

1R-8R, 1L-8L, 4R-5R, 4L-5L, 2R-7R, 2L-7L, 3R-6R, 3L-6L.

18 Cylinder "V" Type Engine

1R-9L, 6R-1L, 8R-6L, 2R-8L, 5R-2L, 7R-5L, 3R-7L, 4R-3L, 9R-4L.

These marks identify cylinders (see "General Engine Data" publication). They are used in conjunction with the timing pointer to determine point of "Fuel Injection" and piston "Top Dead Center".

TIMING POINTER

The pointer is attached to the cylinder block or the outboard bearing housing and extends over the ring gear. The pointer is double ended and is marked according to engine rotation. On standard rotation engines (CCW) the top portion is marked "INJ" and the lower portion "TDC". On reverse rotation engines (CW) the top portion is marked "TDC" and the lower portion "INJ". These marks are used to locate the piston "Top Dead Center".

It is important that the distance between the two pointers and also the location of the pointer be correct when making adjustments to the engine that require use of the timing pointer. To check location of the timing pointer see "Locating TDC of No. 1 Piston" listed in the index.

CRANKCASE EXHAUSTER

DESCRIPTION

The crankcase exhauster, driven by an electric motor, is a centrifugal blower which exhausts crankcase vapors to the atmosphere. The entire assembly is mounted on top of the cylinder block at the power take-off end of the engine.

REMOVAL

1. Disconnect electrical connections to blower motor (conduit).

2. Remove lubricating oil drain pipe (4).

3. Remove mounting hardware and exhaust pipe from discharge side of blower.

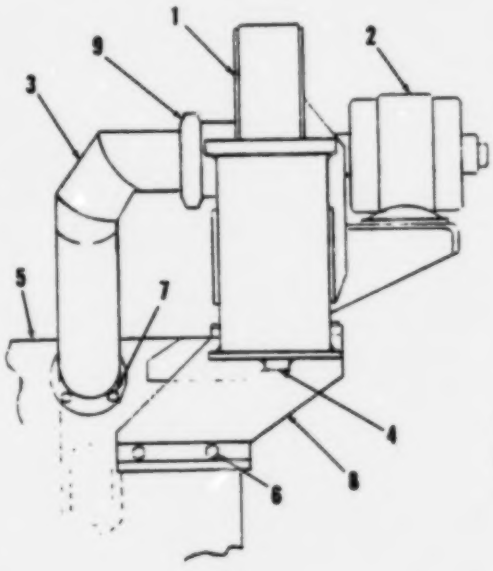
4. Remove capscrews (7), washers and lockwashers connecting exhauster suction elbow (3) to cylinder block (5).

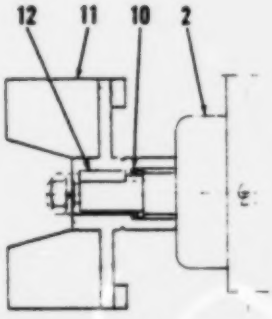
5. Remove capscrews (6), washers and lockwashers holding bracket (8) to block.

6. Lift entire assembly off cylinder block.

7. Remove gasket elbow to block.

8. Loosen clamp (9) and separate motor blower from suction elbow.





SECTION SHOWING ASS'Y
ROTOR TO MOTOR

1. Blower
2. Motor
3. Elbow
4. L.O. Drain
5. Block
6. Capscrew
7. Capscrew
8. Mounting Bracket
9. Clamp
10. Spacer
11. Rotor
12. Key

FIG. 1 - CRANKCASE EXHAUSTER

INSPECTION AND MAINTENANCE

1. Clean blower impeller, housing and fan blades.

2. Clean exhaust and drain piping.

3. Check clearance between impeller and casing.

4. Check for impeller tightness on shaft.

5. Replace gaskets.

INSTALLATION

1. Install new gasket between suction elbow and blower motor and tighten clamp (9).

2. Install new gasket elbow to block.

3. Place assembly on cylinder block and apply lockwashers, washers and capscrews (6) to mounting bracket (8) to block.

4. Apply lockwashers, washers and capscrews (7) to elbow (3) to block.

5. Install lubricating oil drain (4).

6. Install exhaust pipe to discharge side of blower.

7. Apply electrical connections to blower motor.

VALVE LEVER MECHANISM

MODEL 251 ENGINES WITH VALVE ROTATORS

DESCRIPTION

The air inlet and exhaust valves are operated from the camshaft by means of the lifter, pushrod and valve lever assemblies.

Each cylinder unit has a lifter assembly which consists of (Fig. 1) two pushrod lifters having a common shaft as a fulcrum. The shaft is supported by the fuel pump support which is attached to the cylinder block. The lifters have rollers which are forced to follow the profiles of the cams by the valve springs.

The pushrod end of the lifter (Fig. 1) is fitted with a hardened steel seat in which the lower end of the pushrod rests. The upper end of the pushrod is fitted with a hardened steel seat in which the hardened steel spherical ball head adjusting screw of the valve lever rests. These screws are used to adjust valve clearance. The other end of the valve lever bears against the equalizing yokes through a ball and socket joint. Each yoke operates two air or two exhaust valves, each pair of valves being operated from a single cam, pushrod and valve lever.

The equalizing yoke slides up and down on a guide rod. A valve clearance adjustment is provided at one end of the yoke to compensate for differences in valve stem lengths.

Pressurized lubrication is provided for the valve lever mechanism. Individual lines conduct the oil from a common header to the cylinder head. The oil then flows through drilled passages in the cylinder head and valve lever bracket to the valve lever shaft and bushings. The shaft and bracket are designed to keep the lube oil passage aligned.

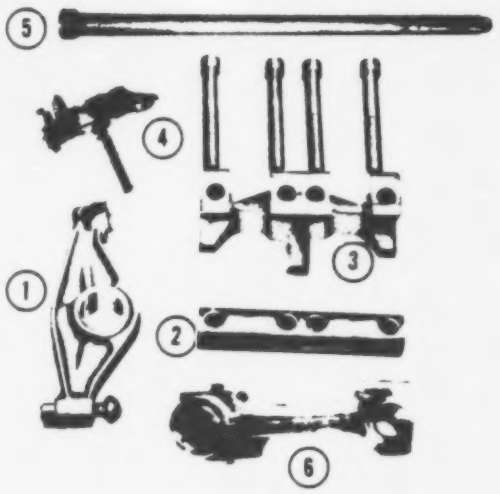
Drilled holes through the valve lever lead the oil from the bushing to the thrust ball joint; a drilled passage in the ball-joint and yoke lubricates the yoke guide and valve stems. In the other direction the oil passes to the ball seat of the adjusting screw. All excess oil follows down the pushrods, lubricating the pushrod lifter rollers and camshaft lobes.

REMOVAL

VALVE LEVERS AND EQUALIZING YOKE

Remove socket head capscrews that secure valve lever bracket to the cylinder head and lift valve assembly from cylinder head.

The equalizing yoke is readily removed from its guide after the levers have been removed.



1. Valve Lever
2. Valve Lever Shaft
3. Valve Lever Shaft Support
4. Equalizing Yoke
5. Pushrod
6. Pushrod Lifter

FIG. 1 - PHOTO 1134
VALVE LEVERS

DISASSEMBLY

VALVE LEVERS

1 Slide valve levers from shaft.

2 Remove if necessary, the snap ring, thrust ball and seat from one end of the lever.

3. Remove adjusting screw from the other end of lever.

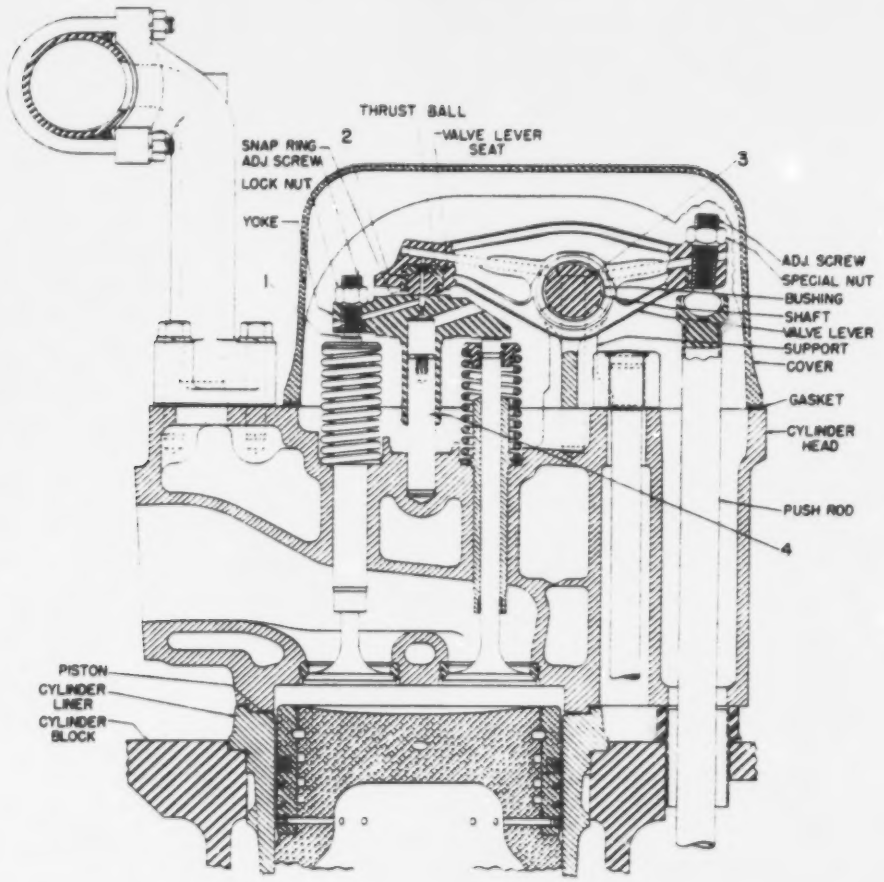


TABLE OF CLEARANCES

1	Valve Clearance (Hot or Cold)	0.034
2	Valve Lever Seat to Valve Lever	0.0005 - 0.0020 Dia. Int.
3	Valve Lever Shaft to Bushing	0.0020 - 0.0035 Dia. cl.
4	Yoke to Yoke Guide	0.0020 - 0.0035 Dia. cl.

FIG. 2 - PHOTO
VALVE LEVER MECHANISM AND CLEARANCES

INSPECTION AND MAINTENANCE

VALVE LEVERS

1. Clean, and surface inspect valve levers.

2. Clean, and surface inspect valve lever bushings and check for wear. If necessary, press out lever bushings for replacement.

3. Surface inspect the ball seat of the valve adjusting screw.

4. Clean and surface inspect the thrust ball and seat. If removal is necessary, remove the old seat by using a puller and press in a new one until it bottoms.

5. Clean and blow out valve lever oil passages.

EQUALIZING YOKE

Clean, surface inspect and check alignment and yoke-to-guide clearance. See Fig. 2, Item 4.

PUSHRODS

Pushrods should be replaced if bent or the ends damaged in any way.

VALVE SPRINGS

The valve springs must be replaced if there are cracks, nicks or scratches.

REASSEMBLY

VALVE LEVERS (See Fig. 2)

1. Oil and apply thrust ball to valve lever seat, locking in place with snap ring. Smooth motion should exist between the thrust ball and seat.

2. Turn the valve clearance adjusting screw up into the valve levers as far as possible. Do not move the adjusting screws again until the valve lever mechanism has been mounted on the engine and the piston has been properly positioned for the adjustment of valve clearance.

CAUTION: The position of the valve clearance adjusting screws in the valve lever, when the valve mechanism is applied to the cylinder head, is extremely important. Should the adjusting screws be in any other position than their upper limit, the piston and valves may be damaged when the crankshaft is rotated.

3. If new valve lever bushings are to be applied, install them with the split at the top. Then burnish to 1.750 to 1.751 inch diameter. Refer to Fig. 2, Item 3, for clearance of shaft to bushing.

4. Slide valve levers onto shaft.

INSTALLATION

1. Place the pushrods in position insuring that the ball seats are properly seated in their sockets on the camshaft followers.

NOTE: Fuel pump support must be installed prior to application of pushrods and valve lever equipment.

2. Place the valve equalizing yokes on their guides with the adjusting nut away from you toward the exhaust manifold.

3. Apply valve lever assembly to cylinder head making certain that the tongue on the end of the valve lever is properly engaged in the slot in the valve equalizing yoke. Apply capscrews and tighten securely.

ADJUSTING VALVE CLEARANCE

Before the valve lash can be set, you must first check the engine timing to insure that the camshaft is in the proper location for valve timing.

LOCATING TDC FOR NO. 1 RIGHT CYLINDER

METHOD 1 — USING TRAMMEL

1. TDC is located when crankshaft is rotated until trammel (see "Tool List" and Fig. 3) can be

fitted between center punch mark on engine base inspection door sill (on left side, power take-off end) and punch mark on crankshaft counterweight.

NOTE: On the 18 cylinder "V" engine, this step (Step 1) is accomplished through the engine base inspection door on the left side, free end.

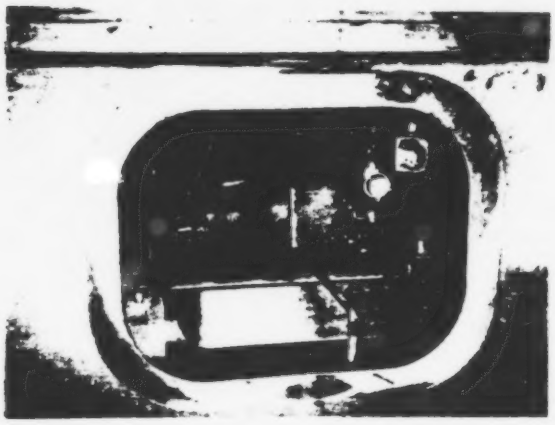


FIG. 3 - PHOTO 7271
TRAMMELING FOR TDC

2. Check the alignment of TDC timing pointer; as per one of the below.

a. Mounted on the left side, power take off end with the mark on the ring gear.

b. In the timing window on the right side cam gear cover for "V" engines and in the timing window on the cam gear cover for 6 cyl. engines.

3. If pointer is not aligned loosen the capscrews holding the pointer and position the TDC mark on the pointer with the 1-6R mark on "V" engines or with #1 on 6 cyl. engines. If there is any doubt regarding trammel accuracy, or if a new crankshaft has been installed, locate TDC in accordance with the timing instructions located in the camshaft MI for your engine.

ADJUSTING VALVE LASH

The valve clearance is 0.034" with the engine cold. The yoke must be lifted by hand before the 0.034" feeler gauge can be inserted.

First Adjustment:

Turn the adjusting screw at the pushrod end of the valve lever until a 0.034 feeler gauge can be inserted between the non-adjustable end of the equalizing yoke and the valve stem, Fig. 4. Leave this feeler in place and tighten the locknut at the pushrod end holding the adjusting screw while tightening the locknut.

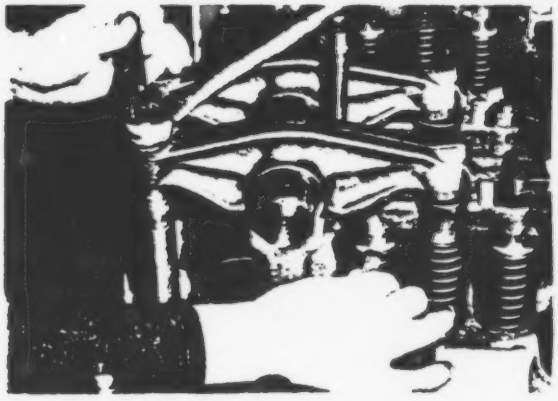


FIGURE 4 - PHOTO
ADJUSTING VALVE CLEARANCE
1ST ADJUSTMENT

Second Adjustment:

Without removing the feeler between the non-adjustable end of the equalizing yoke and the valve stem, turn the adjusting screw on the equalizing yoke until a 0.034 feeler gauge can be inserted between the adjusting screw and valve stem, Fig. 5. With the feeler in place hold the adjusting screw with an Allen wrench while tightening the locknut.

FIG. 5 - PHOTO
ADJUSTING VALVE CLEARANCE
2ND ADJUSTMENT

Recheck both clearances with feelers to make certain that the proper valve clearance exists on both valves.

Notice that once the feeler gauges are removed it will be necessary to lift the equalizing yoke by hand to reinsert the gauges.

Continue through the firing order for checking valve clearance on subsequent cylinders.

CLEARANCES

For clearances of various parts, refer to Fig. 2. For clearances of parts in cylinder head see "Cylinder Head" Maintenance Instruction.

TOOLS

Item	Part No.
Feeler Gauge (0.034") (2 Required)	24700411
Burnish Tool for Valve Lever Bushing	2479932
Timing Tramel "V" Engines	2471325
Timing Tramel 6 Cyl. Engine	2471324

MODEL DIFFERENCE SHEET

FUEL INJECTION EQUIPMENT MAINTENANCE

The purpose of this Model Difference Sheet is to identify procedures that differ from those shown in your Maintenance Instruction.

Please retain this MDS with MI-11267.

The maintenance in this Publication related to the fuel injection pump is not applicable to your engine. Refer to Bryce Publication No. 79, issue 1 (12.80) for maintenance.

Data subject to change without notice.

FUEL INJECTION EQUIPMENT MAINTENANCE

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MODEL DIFFERENCE SHEET

FUEL INJECTION EQUIPMENT MAINTENANCE

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ADD TO TABLE 1, PAGE 15:

NOZZLE TYPE	MAXIMUM LIFT		PART NO.
	Inches	MM	
H157T32K493	0.013	0.33	22310235
H157T35K493	0.013	0.33	22310236
H157T37K493	0.015	0.38	22310237
H157T40K648	0.017	0.43	22310238

Data subject to change without notice.

FUEL INJECTION EQUIPMENT
INSTALLATION, MAINTENANCE, AND RECONDITIONING

INTRODUCTION

The following instructions provide complete information for the maintenance and care of the fuel injection equipment used on Model 251 diesel engines.

These instructions are divided into four sections: "Description and Operation," "Maintenance of Pumps," "Calibration of Pumps," and "Maintenance of Nozzles and Holders."

The maintenance procedures described are based on the use of special tools. For ease of identification, these tools are identified by a symbol# in the text.

Before attempting to maintain fuel injection equipment, maintenance personnel should first become familiar with the equipment by reading the "Description and Operation" section. This section contains cross sectional illustrations which will also be useful when studying the maintenance instructions.

"Condemning Limits" referred to and recommended in these instructions represent maximum or minimum values for reuse of the specific part mentioned to insure satisfactory performance for a reasonable period of service.

DESCRIPTION AND OPERATION

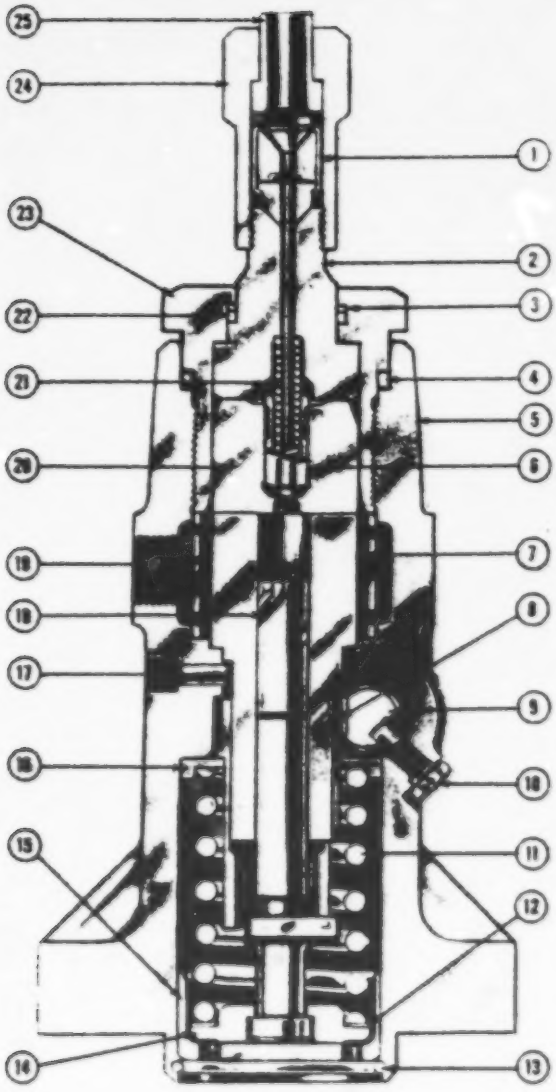
DESCRIPTION

The fuel injection pump, shown in Fig. 1, is a constant stroke, lapped plunger type and is operated from a camshaft through an adjustable tappet. The three functions of the fuel injection pump are: To raise the fuel oil pressure to a value which will efficiently atomize the fuel; to supply the correct quantity of fuel to the injection nozzle in response to governor demand; and to time the delivery of the fuel at a definite point in the engine cycle, and within a limited number of degrees of engine crankshaft rotation.

The pump (Fig. 1) consists primarily of a housing (Item 5, Fig. 1), delivery valve (Item 6, Fig. 1), and spring (Item 21, Fig. 1), delivery valve holder (Item 2, Fig. 1), pumping elements (consisting of a plunger) (Item 18, Fig. 1), plunger barrel (Item 7, Fig. 1) and a plunger spring (Item 11, Fig. 1), a geared control sleeve (Item 8, Fig. 1) and a control rack (Item 9, Fig. 1). The fuel injection nozzle holder (Fig. 3) conducts the fuel from the pump and discharge tubing to the fuel injection nozzle (Fig. 2) and provides a means of adjusting the nozzle valve opening pressure. The nozzle (Fig. 2) atomizes and directs, in a definite spray pattern, the fuel into the combustion chamber.

The components of the nozzle holder (Fig. 3) are the holder body, pressure adjusting spring, shims, spacer, nozzle body with cap nut and valve stop spacer.

The fuel injection nozzles are the closed, hydraulically operated, differential type. The nozzle (Fig. 2) consists of the nozzle body and the nozzle valve. To minimize wear and promote durability, the body is made of nitrided steel and the needle valve of through hardened steel. The nozzle valve and valve body are mated together to form a selected assembly. These parts, therefore, cannot be exchanged singly, but must be replaced, when necessary, as a unit.



1. Snubber Valve Assembly
2. Delivery Valve Holder
3. Leather Backup Ring
4. "O" Ring
5. Pump Housing
6. Delivery Valve
7. Barrel
8. Control Sleeve
9. Control Rack
10. Control Rack Stop Screw
11. Plunger Spring
12. Washer
13. Guide Cup Retaining Ring
14. Lower Spring Seat
15. Guide Cup (Short Style)
16. Upper Spring Seat
17. Barrel Locating Pin
18. Plunger
19. Baffle Ring
20. Delivery Valve Body
21. Delivery Valve Spring
22. "O" Ring
23. Delivery Valve Holding Nut
24. Tubing Union Nut
25. Tubing Union Nut Sleeve

FIG. 1 - PHOTO 8016
FUEL INJECTION PUMP USED ON 251 ENGINES

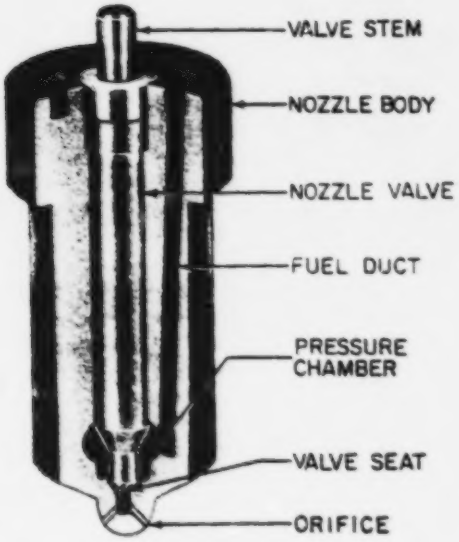


FIG. 2 - PHOTO 6540
TYPICAL INJECTION NOZZLE

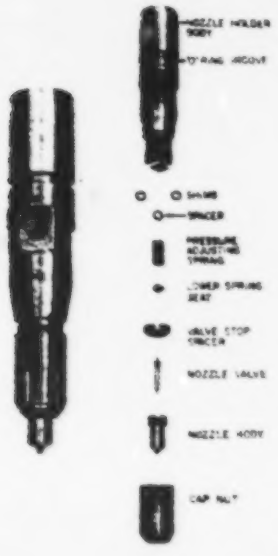


FIG. 3 - PHOTO 6539
NOZZLE AND HOLDER TYPE AKK (242T5700A)

At the tip of the nozzle body are several spray holes (Fig. 2) through which the fuel passes into the combustion chamber. A spring loaded nozzle valve, which seats above the spray holes, controls the fuel flow. This valve will open when the fuel pressure exceeds the spring force and will close after each injection of fuel.

OPERATION

Fuel oil enters the pump (Fig. 1) under pressure from the fuel oil header and fills the sump surrounding the plunger barrel (Item 7, Fig. 1). When the plunger (Item 18, Fig. 1) is at the bottom of its stroke, the fuel flows through the barrel ports filling the space above the plunger as well as the cutaway area of the helix. As the plunger (Item 18, Fig. 1) moves upward, the barrel ports close. Further upward movement of the plunger begins to raise the pressure of the trapped fuel within the barrel.

When the pressure is sufficient to overcome the force exerted on the delivery valve (Item 6, Fig. 1) by the delivery valve spring (Item 21, Fig. 1) the delivery valve (Item 6, Fig. 1) opens, and the fuel is discharged into the fuel injection tubing.

Delivery of fuel ceases when the plunger helix (Item 18, Fig. 1) opens the barrel ports. During the remainder of the plunger stroke, fuel spills into the sump. This termination of fuel delivery by the helix controls the quantity of fuel delivered per stroke.

The angular position of the plunger (Item 18, Fig. 1) with respect to the barrel ports, determines the effective stroke and, therefore, the quantity of fuel injected. The total length of the plunger stroke remains constant regardless of engine speed or load. The plunger (Item 18, Fig. 1) is rotated by the control sleeve (Item 8, Fig. 1), the lower end of the sleeve being slotted to engage the flanges of the plunger (Item 18, Fig. 1). The upper end of the control sleeve (Item 8, Fig. 1) has a gear segment which engages the control rack (Item 9, Fig. 1). Movement of the control rack by the engine governor rotates the plunger (Item 18, Fig. 1), thereby varying the quantity of fuel delivered by the pump. A baffle ring (Item 19, Fig. 1) surrounds the barrel (Item 7, Fig. 1) and serves to prevent erosion of the pump housing as a result of sudden oil pressure increases when the barrel ports are uncovered.

The delivery valve (Item 6, Fig. 1) prevents excessive draining of fuel from the injection tubing as the plunger helix (Item 18, Fig. 1) uncovers the barrel ports, at which time there is a sudden pressure drop below the delivery valve (Item 6, Fig. 1) and the valve

closes. As the valve (Item 6, Fig. 1) snaps into its seat, the pressure is reduced in the injection tubing below the closing pressure of the nozzle. This action of the valve eliminates the possibility of secondary injection (after-dribble) at the nozzle.

The reduction of pressure in the injection tubing is brought about by an accurately fitted relief piston at the upper end of the delivery valve stem.

When the plunger helix (Item 18, Fig. 1) first uncovers the barrel spill ports the lower edge of the piston passes into the valve body (Item 20, Fig. 1) and traps all fuel in the injection tube. Further movement of the valve (Item 6, Fig. 1) to its seat increases the space available for the fuel in the tube and, therefore, greatly reduces the fuel pressure. The delivery valve (Item 6, Fig. 1) also acts as a check valve to prevent cylinder gas from blowing back into the pump if a nozzle is stuck open.

A snubber valve (Item 1, Fig. 1) located in the high pressure tubing union nut (Item 24, Fig. 1) is used to dampen fuel flow pulsations in the high pressure injection tube, thereby preventing damage to the tube. It also acts basically as a check valve restricting fuel flow in the reverse direction through a small orifice. The metered quantity of fuel from the injection pump passes through the snubber valve (Item 1, Fig. 1) and high pressure line entering the nozzle holder at the high pressure tube inlet connection.

Drilled passages in the holder conduct the fuel to the nozzle pressure chamber adjacent to the differential section of the valve.

When the pressure of the fuel acting on the differential section of the valve exceeds the spring pressure, the valve is forced from its seat. Fuel flows through the nozzle spray holes until the fuel pump ceases to deliver fuel. The fuel flow is then instantaneously and positively cut off as the spring snaps the valve shut.

Leakage of fuel between the nozzle valve and nozzle body is necessary for lubrication. The fuel accumulates above the nozzle valve and in the spring compartment. From the spring compartment the fuel drains out of the nozzle holder through a leakoff passage thus preventing the nozzle valve from becoming hydraulically locked and causing the nozzle to become inoperative.

REMOVAL

Refer to index for maintenance instruction publications for "Fuel Injection Pump Support and Drive," and "Cylinder Head". Upon removal of fuel pump support cover and aligning timing mark as specified, loosen the high pressure fuel line connection at the pump and nozzle holder. Remove snubber valve (Item 1, Fig. 1) and swing away from pump.

Disconnect pump rack (Item 9, Fig. 1) from fuel pump control lever. Disconnect header from fuel pump by removing header bolts and washers. Remove securing capscrews on mounting flange of pump and lift off.

Remove nozzle holder retaining clamp stud nuts at cylinder head. Remove retaining clamp and pull nozzle and holder with puller#. There is no gasket between the nozzle holder cap nut and the rolled sleeve in the cylinder head.

NOTE: When any part of the fuel injection system is disconnected or removed, even for a short period of time, cover or plug the openings.

MAINTENANCE OF PUMPS

PLUNGER GUIDE CUP, PLUNGER AND CONTROL SLEEVE

Before attempting to disassemble a fuel injection pump, it is important to have clean tools and a clean work bench. Cover the bench with clean paper and rinse parts, as they are removed, in clean oil.

Place the pump in a dismantling fixture, (spring depressor)# in an inverted position and force the plunger guide cup into the pump housing. (See Fig. 5). Insert a piece of drill rod (or heavy wire) into the hole on the inside of the pump body to hold the guide cup down.

Remove the guide cup retaining ring (Fig. 6). Again, force the guide cup down and remove the drill rod. Release the force on the guide cup and remove the cup.

With the guide cup removed, lift the lower spring seat, plunger, and plunger spring out of the pump body. After removing the valve spring, remove the baffle ring. Remove the control sleeve (Fig. 8) with

the upper spring seat. Wash the plunger separately to prevent it from being scratched by coming in contact with other parts. Place gently on bench to prevent damage.

Guide cups should not be reused when either of the surfaces which are contacted by the tappet screw or the plunger are indented more than 0.005". The clearance between the guide cup body and the pump body has no effect on pump performance. Condemnation should be based on mechanical judgement.

Springs and spring seats will rarely require replacement. Replace them, however, if they are badly worn.

DELIVERY VALVE

Remove the pump from the dismantling fixture (spring depressor)#. Reinstall in the fixture in an upright position. With a socket wrench, loosen the delivery valve holding nut (Fig. 4).

NOTE: In loosening the nut, exert a strong steady pull on the wrench. Never use a hammer or exert a jerking pull on the wrench to loosen or tighten.

Remove the delivery valve holding nut (Fig. 4 & 7), the valve holder and "O" rings. Remove the delivery valve spring. Remove the delivery valve and the delivery valve body as a unit. Wash the delivery valve and valve body separately to prevent them from being scratched by coming in contact with other parts. Examine the holding nut for damaged threads or seat. Renew if necessary. Examine the delivery valve holder seat; lap if necessary using the same method and tolerances described for the plunger barrel. The delivery valve spring must not be pitted or nicked. Check for cracks and replace any questionable spring.

If necessary, reseat the valve by lapping it with the valve body by using a small amount of lapping compound#.

It should be noted that contact at the small diameter of the seat only is required, otherwise calibration will be affected. It is recommended that only very light lapping, if any, be performed. Be extremely careful not to allow any lapping compound to get on the relief piston, valve flutes or bore of the valve body.

Examine the surface of the valve body which contacts the plunger barrel, and the delivery valve holder and lap if necessary. Use the same methods and tolerances for lapping as described for plunger barrel.

The valve and valve body are a mated assembly and, therefore, cannot be replaced individually. If either one cannot be reused, the complete unit must be replaced.

PLUNGER BARREL

Remove the plunger guide cup (Item 15, Fig. 1), plunger (Item 18, Fig. 1) and control sleeve (Item 8, Fig. 1). The plunger barrel is slotted, making it unnecessary to remove the locating pin (Item 17, Fig. 1) in order to remove the barrel.

Push the barrel out through the delivery end of the pump with a hammer handle or screw driver handle. Wash the plunger barrel separately to prevent it from being scratched by coming in contact with other parts.

Fine scratches, scuff marks and a dull appearance of the plunger indicates wear caused by abrasives in the fuel oil. This wear, particularly if on the upper portion of the lapped surface above the helix, greatly reduces the accuracy of delivery of fuel and, consequently, affects engine performance. Plungers in this condition should be replaced, particularly if they do not calibrate satisfactorily.

If dark discoloration and pit marks are observed, this could indicate corrosion caused by fuel oil containing destructive acids or water. Consequently, the grade of fuel oil and the filtering system should be investigated. If the plunger is corroded, has pit marks, or if the plunger helix is rough or worn, it must be replaced. Refer to Fig. 10 for example of erosion.

Examine the plunger barrel carefully, particularly the lapped end. If this surface indicates high pressure leaks, remove the marks with a surface plate charged with lapping compound#. To charge a surface plate, apply a small amount of lapping compound on one surface plate and wet the compound with fuel oil. Move the plate over a second surface plate with a figure eight motion. Wipe both plates clean. After dampening with calibrating or fuel oil either plate may now be used. The lapped surfaces must be held to a flatness of 2-1/2 light bands maximum and 4 RMS finish.

FIG. 4 - PHOTO 50
LOOSENING DELIVERY VALVE HOLDING NUT

Inspect the baffle ring (Item 19, Fig. 1) for erosion. If erosion has progressed to any significant extent the baffle rings should be replaced. The plunger and barrel are a mated assembly and, therefore, cannot be reused individually. If either one cannot be reused, the complete unit must be replaced. It is highly recommended, at this point, that the plunger and barrel be reassembled for protection against possible damage.

CONTROL RACK AND BUSHINGS

After removing the plunger guide cup, plunger, control sleeve, delivery valve and plunger barrel by methods previously described, remove the control rack stop screw (Item 10, Fig. 1) slide the rack out of its bushings. Using a bushing removal tool,# press out one rack bushing and allow it to fall out through the opening in the bottom of the pump (Fig. 9). Remove the second bushing in the same manner.

Examine gear teeth on the control rack for possible excessive wear. Slight wear is normal and replacement is rarely required. The control rack-to-sleeve and the control rack-to-plunger lost motion should be measured during reassembly of the pump.

PUMP ASSEMBLY

Before assembling a fuel injection pump, wash all parts in clean fuel oil, assembling them wet. Assemble these parts in the same sequence as are called out in the following instructions.

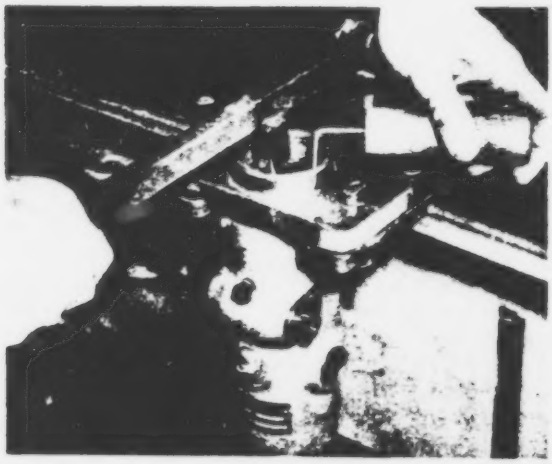


FIG. 5 - PHOTO 2543
COMPRESSING GUIDE CUP

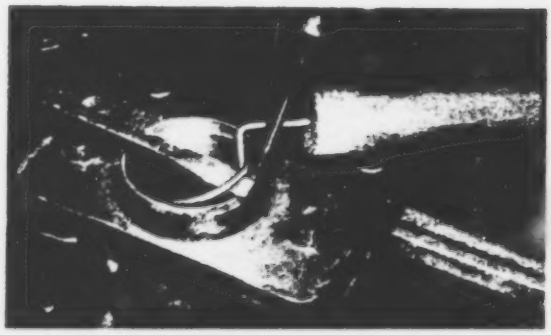


FIG. 6 - PHOTO 45
REMOVING GUIDE CUP RETAINING RING

CONTROL RACK BUSHINGS

Place the pump housing (Item 5, Fig. 1) on an arbor press and press in one bushing at a time with a bushing application tool,# (Fig. 9). After both bushings are installed, ream the bushings to 0.7185" - 0.7192". To prevent bushings from becoming egg-shaped, use a "T" handle wrench on the end of the reamer# and start the reamer carefully, holding it in line with the bushing bore, (Fig. 11). After reaming, thoroughly clean pump body.

PLUNGER BARREL

Re-examine the plunger barrel seat in the pump housing. Do not attempt to refinish the barrel seat, but remove any dirt that is found. This seat must be

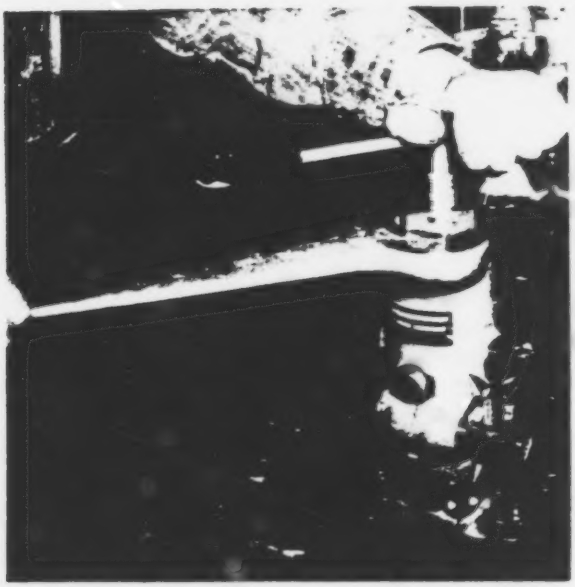


FIG. 7 - PHOTO 52
REMOVING DELIVERY VALVE HOLDING NUT

FIG. 8 - PHOTO 46
REMOVING CONTROL SLEEVE

tight so that during pump operation, fuel will not leak past the seat into the spring chamber.

Place the pump housing in a dismantling fixture (spring depressor)# in an upright position. Start the plunger barrel (Item 7, Fig. 1) into the pump housing guiding it with a clean hammer handle or screw driver handle inserted into the bottom of the housing. The barrel is located in the housing by a pin in the pump housing (Item 17, Fig. 1) and a slot on the outside of the barrel. After the barrel is lowered into the housing, move the barrel up and down and rotate it slightly to insure that it is properly located. Apply baffle ring (Item 19, Fig. 1) over the barrel.

DELIVERY VALVE

Lower the delivery valve assembly and delivery valve spring into the pump housing. Apply a liberal amount of vaseline to a new "O" ring (Item 22, Fig. 1) and a new back-up ring (Item 3, Fig. 1). Place "O" ring and back-up ring on the delivery valve holder and install the holder over the delivery valve spring. Apply a new "O" ring (Item 4, Fig. 1) to the delivery valve holding nut (Item 23, Fig. 1). Screw the holding nut into the pump housing and then torque to 450 - 500 ft. -lbs. It is suggested, at this time, to cover the opening for protection.

CONTROL RACK AND CONTROL SLEEVE

Remove the pump from the dismantling fixture.# Reinstall the pump in the fixture in an inverted position. Slide the rack (Item 9, Fig. 1) into its bushings rotating it until the matched tooth on the rack is visible through the bottom opening of the pump.

Apply the control rack stop screw (Item 10, Fig. 1) and engage it with the slot in the rack. Tighten the screw and lockwire it to the pump housing. Lower the control sleeve into the pump housing and engage the rack so that the notches on the sleeve and rack are in line (Fig. 12). With the sleeve held stationary, the limit of rack movement is 0.009". With the plunger held stationary, the limit of rack movement is 0.015".

PLUNGER AND PLUNGER GUIDE CUP

Install the upper spring seat (Item 16, Fig. 1) and plunger spring (Item 11, Fig. 1) in the pump housing. Apply the lower spring seat (Item 14, Fig. 1) with

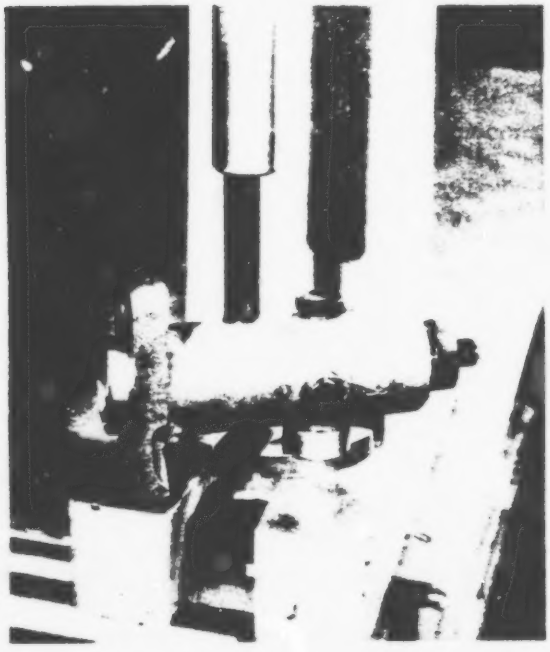


FIG. 9 - PHOTO 47
RENEWING RACK BUSHINGS

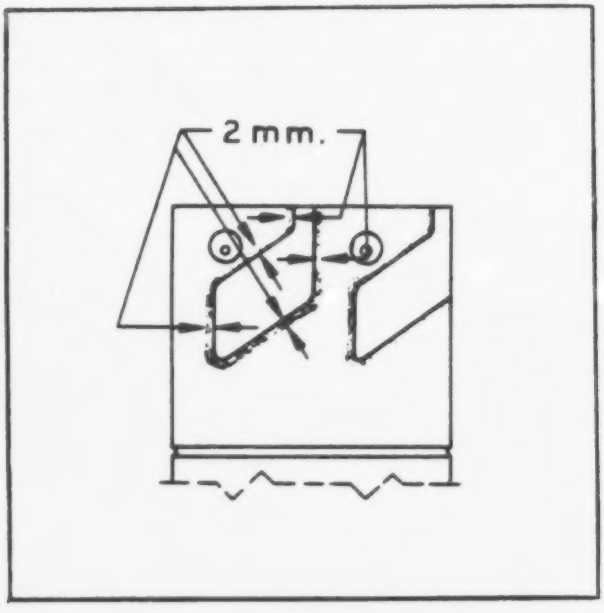


FIG. 10 - PHOTO 3617A
FUEL PUMP PLUNGER EROSION

washer (Item 12, Fig. 1) to the plunger (Item 18, Fig. 1) and insert the plunger into the barrel (Item 7, Fig. 1) so that the notches on the plunger flange and control sleeve are in line (Fig. 12).

Slide the plunger guide cup (Item 15, Fig. 1) into the pump body. Force the guide cup down against the spring pressure making certain that the flange on the plunger engages the slots in the control sleeve. Insert a piece of drill rod (or heavy wire) in the hole on the inside of the pump body to hold the guide cup down. Apply the guide cup retaining ring (Item 13, Fig. 1). Force the guide cup down and remove the drill rod (or heavy wire). Release the guide cup.

Once the pump is completely assembled, check the rack movement. The rack should slide easily. Calibrate the pump.

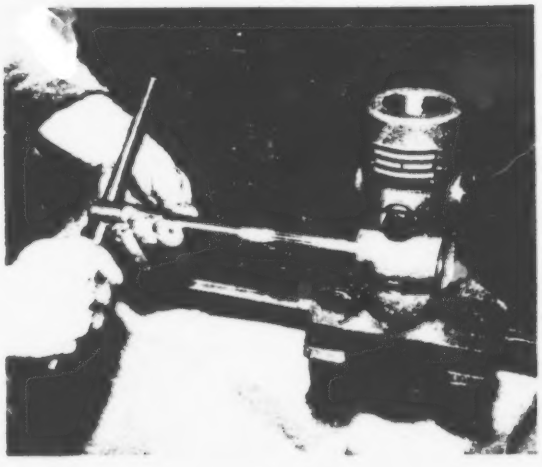


FIG. 11 - PHOTO 49
REAMING RACK BUSHINGS

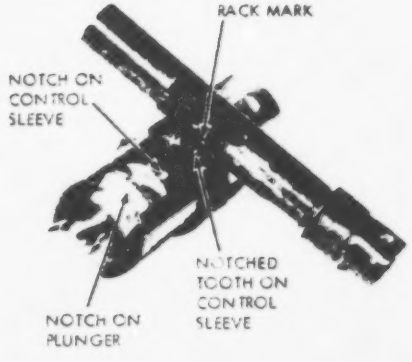


FIG. 12 - PHOTO 3314
ALIGNING TIMING MARKS

MAINTENANCE OF NOZZLES AND HOLDERS

NOZZLE TESTING

Wipe all dirt and loose carbon from the nozzle assembly with a clean cloth and clean the nozzle tip with a brass wire brush.

The criteria for a good nozzle is good atomization, free movement of the nozzle valve, and no leakage at the seat.

Using a test stand,# shown in Fig. 13, check the following nozzle characteristics: spray pattern, opening pressure, tightness of valve seat and leakoff-rate. If any of these requirements as described in the following paragraphs are not met, the nozzle and holder must be disassembled and reconditioned. See "Disassembly of Nozzle and Holder" section, this maintenance instruction.

Before accepting the test stand pressure gauge readings, one must be certain that the gauge is accurate. It should be checked periodically on a dead weight tester and calibrated.

After mounting the nozzle in the test stand (Fig. 13) check the following characteristics:

SPRAY PATTERN

With the test stand pressure gauge shut off, pump the tester handle rapidly (approximately one stroke per second) and note the spray pattern. Fuel should discharge from all nozzle holes and the spray pattern should be uniform.

OPENING PRESSURE

Pump the tester handle slowly and record the opening pressure of the nozzle valve. The opening pressure for new nozzles and holders should be 3700-4050 psi. If a nozzle and holder assembly is being reworked, set the opening pressure at 3700-4050 psi. The pressure will usually settle to 3700 psi when the nozzle is in the engine. Any nozzle valve that opens at 3700 psi should not be reset.

To adjust the nozzle valve opening pressure shims are applied or removed at the top of the adjusting spring (see Fig. 3).

Both ends of the spacer and upper end of the nozzle body are ground and lapped to provide a leakproof and pressure tight seal. This eliminates the necessity of a gasket and makes it easier to remove and reapply the nozzle to the nozzle holder.

TIGHTNESS OF VALVE SEAT

Close the pressure gauge shutoff valve to avoid damage to the gauge. Pump the handle of the test stand rapidly several times (one stroke per second). If a drop forms at the tip of the nozzle, the valve seat is leaking. Wipe the end of the nozzle with a clean dry cloth.

Open the gauge shut-off valve and slowly raise the pressure to within 100 psi of the specified opening pressure as listed under "opening pressure". Hold this pressure for ten seconds. If fuel appears on the nozzle tip, the valve seat is leaking. This may be caused by dirt between the valve and seat or, by an improper valve or seat face. If, after the nozzle is cleaned (see "Nozzle Cleaning" section, this maintenance instruction) the valve seat continues to leak, the nozzle must be reconditioned (see "Nozzle Reconditioning" this maintenance instruction). If a reconditioned nozzle leaks, the following steps should be taken:

A. Relap seat and re-test
B. Regrind valve and re-test
C. Scrap

NOZZLE CHATTER

The tendency not to chatter is not in itself a sufficient criteria for condemning nozzles, but instead, a more reliable criteria is seat tightness.

If the needle valve is free, which can be determined by a sharp blow of the hand pump, and if no leakage appears at the seat, the nozzle will perform just as well even though it has no high pitch chatter.

The needle valve diameter and seat diameter ratios determine whether or not there will be nozzle chatter. The needle ratio determines the blow-down or difference between opening and closing pressures and, therefore, the tendency to chatter. The smaller the ratio, the easier it is to make it chatter.

while the larger ratios will not chatter so easily. At one time, smaller ratio nozzles were used but presently, the larger ratio nozzles are being used to fit the particular combustion characteristics of the engines to which they are applied.

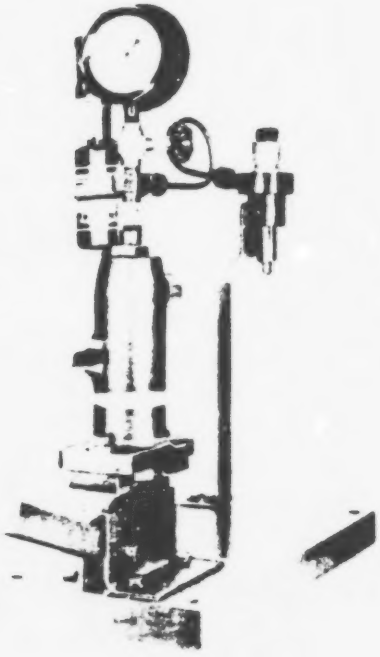


FIG. 13 - PHOTO 8371
NOZZLE TEST STAND

NOZZLE LEAK-OFF RATE

Use a test fixture,# Fig. 14, which has a fixed volume chamber and is installed in the hand test pump line adjacent to the nozzle holder with shut-off valve and gauge.

This fixture provides a positive shut-off ahead of the nozzle and eliminates variations between hand pump stands and possible delivery valve leakage. The limits of leakage time in seconds for a pressure drop from 3500 to 1000 psi and using a 0.107" X 12" tubing is as follows:

"T" Size	New	19
	Used	6

The effect of nozzle leak-off on delivered fuel is negligible provided leak-off does not exceed the above values.

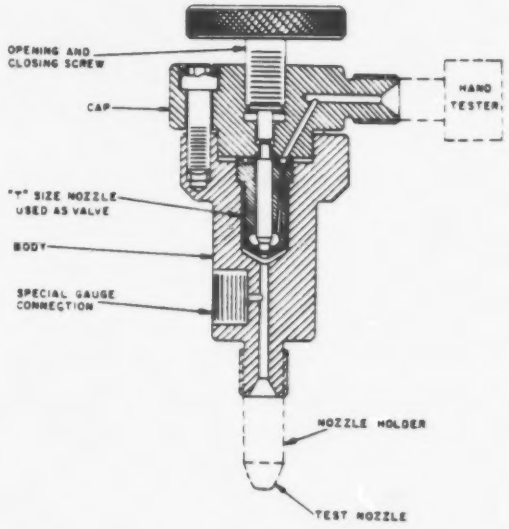


FIG. 14 - PHOTO 3645
NOZZLE LEAK-OFF FIXTURE

DISASSEMBLY OF NOZZLE AND HOLDER

A nozzle and holder must be disassembled on a clean work bench with clean tools. As all parts are removed, they must be rinsed in clean fuel oil and then blown dry with clean filtered air.

To disassemble a nozzle and holder (Fig. 3) first unscrew the cap nut using a box wrench of proper size. Lift the nozzle out of the holder, being careful that the nozzle valve does not drop out of the nozzle body.

If carbon formation has caused the nozzle to be stuck in the cap nut, carefully drive it out with the nozzle extractor# or a brass rod, one end of which conforms to the contour of the nozzle tip (Fig. 15). The nozzle valve and body are a mated assembly so it is important not to mix them up with other assemblies.

Remove valve stop spacer, lower spring seat, pressure adjusting spring and shims from holder.

To insure protection of the lapped surface of the nozzle holder, reapply the nozzle cap nut to the holder.

NOZZLE CLEANING

Soak the nozzle in clean fuel oil and withdraw the nozzle valve from the nozzle body. If the nozzle valve cannot be withdrawn easily, soak the nozzle in a cleaning solvent. A recommended solvent is Bendix "Metal-clene" or suitable equivalent. If the valve still cannot be removed after thoroughly soaking, remove the nozzle valve with a valve ejector# as illustrated in Fig. 17.

Examine the valve and valve body for gum and carbon deposits. If deposits are present, soak the nozzle valve and valve body in a solvent as mentioned above. Cleaning may require from a few minutes to several hours depending on the cleaner used and the condition of the nozzle body and valve.

FIG. 15 - PHOTO 61
REMOVING NOZZLE FROM CAP NUT

NOZZLE HOLES

After the nozzle body has been soaked sufficiently, blow out the nozzle holes with clean dry air. If necessary, clean the holes with a needle# (gray wire) smaller than the spray hole (Fig. 16). Be careful not to break-off the needle as it is very difficult if not impossible to remove the broken pieces.

Hole wear (bell mouthing) is not a problem. Even though wear would increase fuel delivery slightly, the nozzle would normally be condemned for lift before atomization and combustion would be affected.

NOZZLE BODY

To clean the nozzle body, soak in cleaning solvent (Bendix Metal-Clene or equivalent).

NOZZLE VALVE

Rinse the nozzle valve and body in clean fuel oil to remove all traces of foreign material. Using the fuel oil as a lubricant, slide the valve into the nozzle body. The valve should slide into the body without any binding with the body held at 45° angle.

FIG. 16 - PHOTO 64
CLEANING NOZZLE HOLES

If the valve binds in the body, spread a small amount of mutton tallow# on the valve shank. Work the valve in the valve body, using a combined back

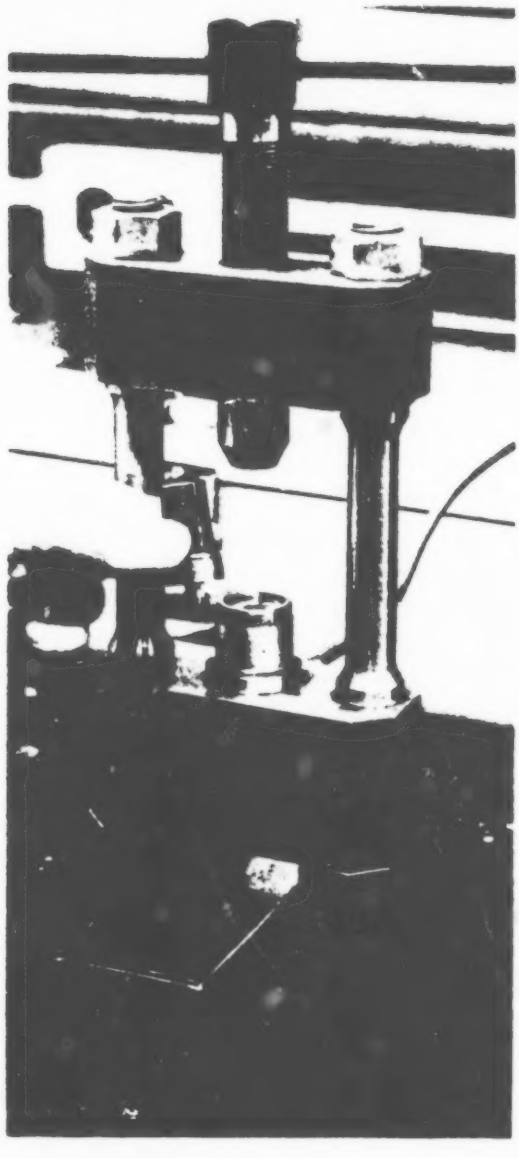


FIG. 17 - PHOTO 2849
REMOVING VALVE FROM VALVE BODY

and forth rotating motion, being careful not to strike the valve seat. Periodically rinse both the valve and body in clean fuel oil during the cleaning operation. If the valve still binds in the valve body, apply a small amount of lapping compound# to the valve shank and again work the valve in the valve body.

CAUTION: Never use hard or sharp tools and emery or crocus cloth on nozzle valves. Valves may also be cleaned with mutton tallow# rubbed on the valve with a felt pad.

NOZZLE RECONDITIONING

GENERAL

In order to properly recondition a fuel injection nozzle, the operator must know the results to be attained. Fig. 21 shows a sectional view of a nozzle with the nozzle valve on its seat. Letter "A" in the illustration denotes that line on the valve which makes contact with the nozzle body forming a leakproof seal. Letter "B" represents the angular clearance between the valve and body.

The method of achieving what has just been described is not difficult, but it does require a reasonable amount of training and some special equipment.

Before any attempt is made to recondition a nozzle, the nozzle must be clean (see "Nozzle Cleaning" - this maintenance instruction) and the valve lift checked to determine whether the nozzle can be reconditioned.

To check the valve lift, use a special lift indicator# shown in Fig. 18.

1. Select the contact piece for the indicator. After application, check for freedom of movement of the contact piece.

2. Loosen the body setscrew and position the body so that the end of the contact piece extends below the bottom of the body approximately 1/16".

3. Place a straight edge across the contact piece and push the contact piece up until the straight edge contacts the tool body. In this position, set the dial indicator at zero. Remove the straight edge.

4. With the nozzle valve and body assembled, engage the extended end of the nozzle valve in the hole of the contact piece. Push the nozzle and body up until the nozzle body contacts the body of the tool. In this position, the reading on the dial indicator is the nozzle lift and corresponds to the upswept portion of the dial hand from this reading to zero.

The limit of valve lift on nozzles is shown in Table I. If the lift is less than the condemning limit, the nozzle can be reconditioned. If equal to or

FIG. 18 - PHOTO 2848
CHECKING NOZZLE VALVE LIFT

greater than the condemning limit, the nozzle must be scrapped.

TABLE I

NOZZLE LIFT CONDEMNING LIMITS

MODEL 251 ENGINES

NOZZLE TYPE	MAXIMUM LIFT		PART NO.
	Inches	MM	
ADL-145-TM-827-6	0.021	0.53	22310224
ADL-145-TM-829-6	0.020	0.51	22310226
ADL-145-TM-830-6	0.023	0.58	22310227
ADL-145-TM-836-6	0.020	0.51	22310230

NOTE: Refer to your index for the correct nozzle type.

CAUTION: When the nozzle has reached or exceeded the lift condemning limit the valve seat has worn appreciably thereby reducing the case hardness depth. Any attempt to restore the original lift by grinding and lapping is impractical because the needle valve will penetrate the remaining case hardness.

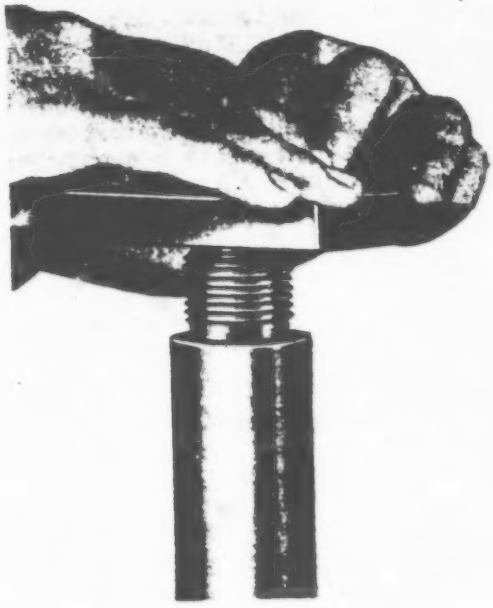


FIG. 19 - PHOTO 68
LAPPING NOZZLE HOLDER

LAPPING NOZZLE BODY SEAT

Examine the seat in the nozzle body with an adequate light source. If the seat is pitted or grooved, it must be refinished with a lapping arbor.#

Nitralloy nozzles are of the shallow, extremely hard case type. This nozzle is so identified by a suffix - 6 in the part number stamped upon it, i.e., ADL-145-TM-827-6. Because of this shallow extremely hard nitralloy case, our experience has indicated that it is more economical to recondition lap nitralloy nozzles only one time. It is recommended that these reconditioned nozzles be so identified. A suggested method is to stamp "R" following the part number; for example, ADL-145-TM-827-6 R.

Insert an arbor in the nozzle body and insert it into the chuck of the lapping machine# shown in Fig. 22. Start the machine and observe whether the arbor runs true. Do not attempt to lap a nozzle body with an arbor that wobbles.

Stop the lapping machine. Apply a small amount of lapping compound# to the conical tip of the arbor and a thin coat of mutton tallow# to the arbor shank.

CAUTION: Do not allow any lapping compound on the arbor shank.

Slide the nozzle body carefully over the lapping arbor until it bottoms. Rotate the body several times to distribute the lapping compound; then start the lapping machine. Work the arbor into the body seat by applying intermittent light pressure and by slowly rotating the nozzle body clockwise. During the lapping operation, frequently inspect both the lapping arbor and the nozzle body seat. If grooves form on the conical tip of the arbor, they must be removed on the valve grinder# (Fig. 23) before continuing.

When the body seat is free of pits and grooves, remove all traces of lapping compound by washing the body in clean fuel oil.

CAUTION: After a lapping arbor has been used, always regrind the conical tip on the valve grinder to a 89 degree included angle.

Never start a lapping operation with an arbor that has not been reground.

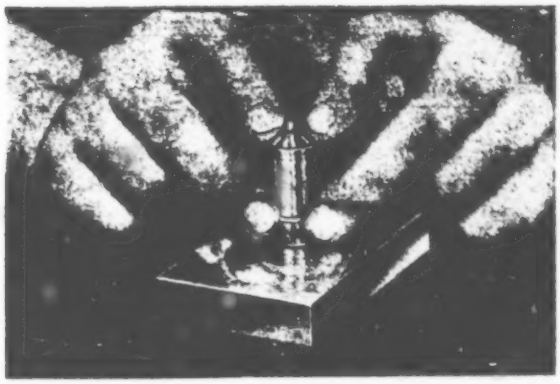


FIG. 20 - PHOTO 67
LAPPING NOZZLE

GRINDING NOZZLE VALVE

Examine the conical tip of the nozzle valve with a magnifying glass. If the tip is in good condition (free from grooves and score marks) it is satisfactory for reuse. Otherwise the tip of the valve must be refinished on the valve grinder. For size "T" nozzles the tip angle is 90 degrees.

Do not remove more material than is absolutely necessary to restore the desired tip angle. Just touching the valve with the grinding wheel is sufficient.

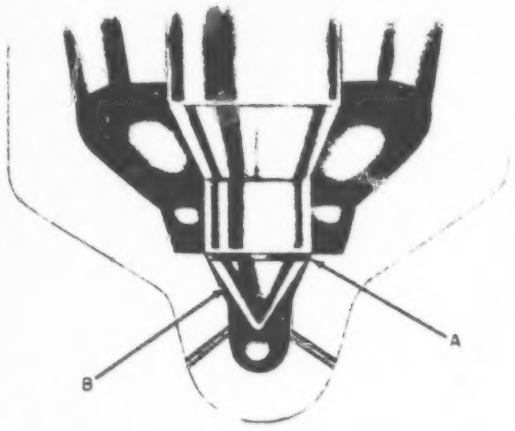


FIG. 21 - PHOTO 70
NOZZLE VALVE SEAT

NOZZLE VALVE AND NOZZLE BODY

Present nozzles have a nitrided body and through hardened needle valve.

The spray holes should be checked. The seat between the body and spacer is lapped as explained in the previous section. The body should then be ultrasonically cleaned.

If there is leakage, the needle valve should be removed and the body seat lapped as previously explained. If a second pop test shows leakage, the needle seat should be reground.

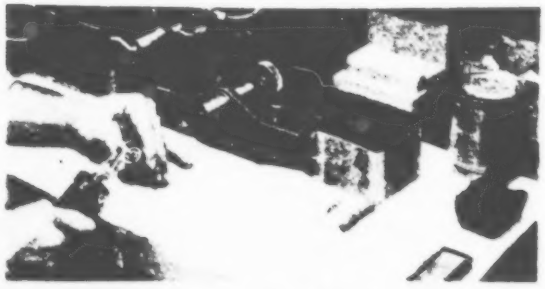


FIG. 22 - PHOTO 71
APPARATUS FOR LAPPING SEAT WITH ARBOR

The included angle of the body seat should be 25 min. to 1 degree less than the needle. The needle valve and body should never be lapped together. Doing this tends to destroy angular difference resulting in a wide seat contact, poor chatter, and a tendency to hold dirt and to leak. Refer to Table I. A greater lift than that shown on the table indicates that the hardened surface of the body has been penetrated beyond the permissible limit.

The increased lift, futhermore, causes a more forceful impact of the valve on the body seat. The combination of these two conditions is harmful, causing the seat to be pounded out after a relatively short period of operation and making the nozzle unfit for further use or reconditioning.

After the nozzle has been reconditioned and the lift checked, test as specified in "Nozzle Testing" section of this publication.

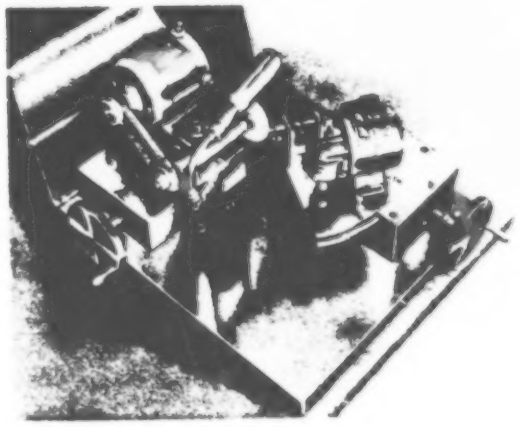


FIG. 23 - PHOTO 2730
NOZZLE VALVE GRINDER

HOLDER RECONDITIONING

GENERAL

Thoroughly clean and examine all parts carefully. In general, very little wear will be noticed. Abnormal conditions, however, such as corrosive fuel or moisture in the fuel, may have caused damage such that parts will require replacement.

HOLDER BODY

The lapped surface at the nozzle end of the holder must be free of cracks or scratches. Cracks or scratches will cause an improper seal between the nozzle holder and the body or spacer. When an indentation of 0.005" is reached in the pressure face at the nozzle end of the holder body, or lower end of spacer, the part must either be replaced or reworked by grinding and lapping to limit nozzle lift.

If the pressure face is reworked, it should only be done once to a depth of 0.005" and suitably marked to prevent further reworking at a future date. The 0.005" depth restriction is mandatory because of the depth of the case hardened surface. Care must be taken when refacing the nozzle end of the body or spacer by grinding to make certain that the surface to be ground remains perpendicular to the axis of the holder or parallel with upper face of spacer.

Small scratches can be removed by lapping as shown in Fig. 19. Charge a lapping plate (use same method as described under "Fuel Pump Plunger and Plunger Barrel") with lapping compound# and move the plate steadily, with no rocking motion, across the surface of the holder until the scratches are removed. Remove all traces of lapping compound with clean fuel oil and blow dry with clean dry air.

The holder threads should be examined to ensure that they are in good condition.

NOZZLE CAP NUT

Remove carbon from both inner and outer surfaces of cap nut using one of the recommended nozzle cleaning solvents (or equivalent). Examine the cap nut for cracks caused by overtightening, and examine the surface of the cap nut that is in contact with the nozzle gasket or nozzle hole sleeve. The seating surface may be reconditioned by rubbing it with fine emery cloth. The nozzle cap nut must be replaced if it is cracked or cannot be reconditioned.

PRESSURE ADJUSTING SPRING

The spring must be replaced if it is scratched, pitted or worn.

VALVE STOP SPACER

Replace the spacer if it is cracked or shows signs of spoiling. Remove any scratches or discoloration on the ends of the spacer with a lapping plate and

FIG. 24 - PHOTO 72
CENTERING NOZZLE IN CAP NUT

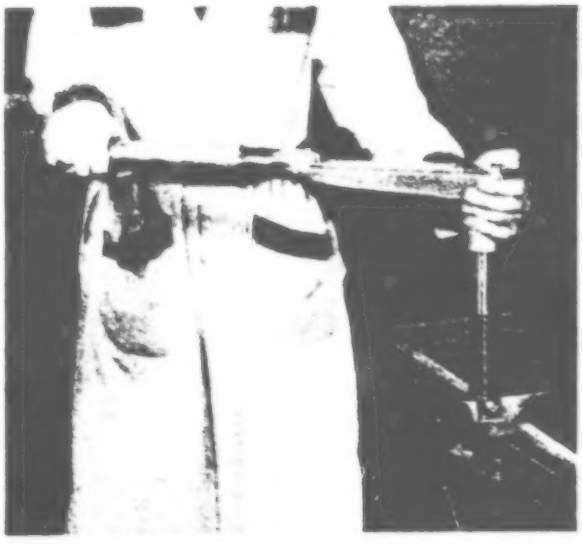


FIG. 25 - PHOTO 59
TIGHTENING CAP NUT

lapping compound#. (Same limits for indentation and grinding as shown for nozzle body).

SPRING SEATS

Replace a spring seat if it is rough or badly worn.

ASSEMBLY OF NOZZLE AND HOLDER

Set the nozzle holder body in a holding fixture with the nozzle end down. Apply the valve stop spacer and then apply the spring seat. Rest the spring on the lower spring seat and the pressure adjusting shims with spacer.

Invert the holder in the holding fixture. Place the nozzle assembly on the nozzle holder and apply the nozzle cap nut. Center the nozzle in the cap nut with a centering sleeve# to prevent side pressure on the nozzle body and hand tighten the cap nut with the centering sleeve in place as shown in Fig. 24. Remove the centering sleeve and tighten the cap nut on the holder with a nozzle, Fig. 25 to torque value as follows:

HOLDER	NOZZLE	TORQUE
AKK (242T5700A)	T	250 - 260 ft.-lbs.

Test the nozzle according to instructions under "Nozzle Testing".

SNUBBER VALVES & FUEL INJECTION TUBES

SNUBBER VALVES

Visually inspect for cracks. Check free movement of the disc by shaking. Examine the disc to see that it is not broken by holding the snubber valve assembly near a light source and looking through the snubber valve orifice.

Note that the orifice in the disc is considerably smaller than the bore in the snubber valve.

FUEL INJECTION TUBE SALVAGE

NOTE: Injection tube end I.D. reduction is caused by excessive tightening of the clamping attachments at each end of the tube to avoid leaks. Salvage is described below. The conical tube ends should be kept at the correct angle by refinishing with the salvage tool fixture#, Fig. 26.

HIGH HORSEPOWER ENGINES

These engines require the use of a high pressure fuel injection tube. These tubes are specially heat treated and identified by the number "4130 ab" or "62036" stamped on the flange face of the sleeve. Part No. 4401031-1. The I.D. of these tubes should not be smaller than 0.0995" dia. (No. 39 drill). If the I.D. at the ends of the tube are less than 0.0995", the tube should be drilled to 0.1065" dia. with a No. 36 drill to a 1/2" depth. Care should be taken to drill on-center so that no step or edge will be formed in the I.D. to cause possible future failure. The edge of the drilled hole should be rounded off 1/64" approximately and the tube then be thoroughly flushed with diesel fuel.

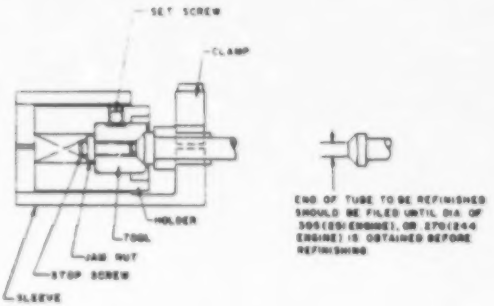


FIG. 26 - PHOTO 3990A
INJECTION TUBE SALVAGE FIXTURE

INSTALLATION OF PUMP, NOZZLE AND HOLDER ON ENGINE

Refer to Fig. 1.

With fuel pump crosshead (in fuel pump support) at bottom of its stroke, place pump in position and pull down with capscrews, but do not tighten.

Connect fuel control rack (Item 9, Fig. 1) to control shaft lever. Tighten socket head capscrew and locknut to securely clamp lever clevis to ball. Shift pump until there is no binding of rack.

Apply pipe connection between pump and header, using new gasket and washers. Tighten header and pump connection evenly. Recheck rack for free movement. Tighten down pump. Torque tighten capscrews to 60 lb. seat. Clean nozzle hole in cylinder head. Apply new "O" ring around nozzle holder.

Apply the nozzle retaining clamp so that the clamp bearing surface is directly over the centerline of the nozzle holder. Tighten the clamp nuts hand tight until the clamp is parallel to the head surface.

Insert fuel injection tube at side making sure that upset cone enters conical seat on side of nozzle body.

Place the snubber valve (Item 1, Fig. 1) on top of fuel pump and apply high pressure fuel line.

Tighten fuel tube clamp screw to 75 ft.-lbs. torque. Tighten only the one retaining clamp nut next to the exhaust manifold to 50 ft.-lbs.

NOTE: Be sure that tubing fits pump correctly so that it will not be under stress. If it is necessary to fit tubing to nozzle and pump for correct alignment, bend tubing carefully, making sure that no sharp corners are made.

Adjust rack travel to correspond with that of remaining pumps on engine. Refer to "Fuel Pump Control Shaft and Crossover Linkage" publication. Check pump timing in accordance with the following procedures:

PUMP TIMING

CAUTION: These instructions will insure proper pump timing only if distance between points of timing pointer, marked "TDC" and "INJ" is correct and pointer is properly located. To check distance

between markings and location of timing pointer, see "Engine Turning Arrangement" publication and section on "Locating TDC for No. 1 Right Cylinder" in "Camshaft" publication.

TIMING MARKS ON ENGINE

Engine timing marks are located on the flywheel ring gear, camshaft gear or generator fan ring.

TIMING MARKS ON PUMP

The pump timing is located on the guide cup (Item 15, Fig. 1) and is visible through a timing window. The present cup uses the top edge as timing reference. Replacement pumps may have a mark for timing on the circumference of the guide cup.

FIG. 27 - PHOTO 8815
FUEL PUMP TIMING MARKS

NOTE: Do not confuse circumferential timing mark with top or bottom ends of shallow relief, machined in long guide cup.

PROCEDURE

1. Remove cover and gasket from timing window on pump.

2. Bar engine over in direction of rotation until timing mark on fuel pump spring guide cup is beginning to rise. (Check direction on instruction plate usually affixed to engine base or block. The standard rotation is counter clockwise when viewed from the power take-off end and reverse rotation is clockwise).

3. Continue to bar engine over until engine timing mark is aligned with "INJ" of timing pointer.

NOTE: Piston of this cylinder is approaching top dead center on its compression stroke, and is at correct crankshaft angle.

4. With this crankshaft setting, timing mark on fuel pump, Fig. 27, guide cup should be line-in-line with stationary mark on pump window.

5 If pump timing mark is not aligned with reference mark on housing adjust timing in following manner:

a. Remove adjusting screw cover, located at bottom of fuel pump support (See Maintenance Instruction publication on "Fuel Pump Support and Drive").

b. Loosen adjusting screw locknut in support and turn adjusting screw either up or down until timing marks in pump timing window are aligned.

c. Retighten locknut.

d. Repeat steps 2 and 3 above.

e. Replace adjusting screw cover.

CAUTION: Timing mark must not go out of sight at either top or bottom of the window. This is very important. If line disappears out of top of window, delivery valve damage may result. If it disappears out of bottom of window, snap ring may shear.

6. Repeat above procedure for remaining pumps following firing order for engine starting with cylinder following one just checked.

7. Re-apply all covers and gaskets.

PUMP CUTOUT LATCH

There is a latch on each fuel pump which fits into a slot in the pump control rack. To cut out any fuel pump, pull out the desired fuel pump rack, flip over the latch and engage it in the slot. The latch in this position, prevents any further movement of the spring loaded operating lever.

TOOL LIST

TOOL	PART NO.
Puller, Nozzle Holder from Cylinder Head	2472021
Fixture, Dismantling (Spring Depressor)	2470343
Rack Bushing Removal Tool	2471642
Rack Bushing Installation Tool	2471652
Rack Bushing Reamer	2471632
Test Stand, Nozzle (Less Pump)	2470513
Test Stand, Nozzle (With Pump)	2470515
Fixture, Nozzle Leak-Off Test (Less Tubes)	2470861
Tube, Pump to Fixture (Required with fixture)	24786211
Tube, Fixture to Nozzle (Required with fixture)	2478629
Extractor, Nozzle from Holder Nut	2471071
Ejector, Nozzle Valve from Valve Body	2470381
Needles, Orifice Cleaning (Pkg. 5):	
Size .25 mm for .275, .300 and .325 mm holes	547181A
Size .30 mm for .325 and .350 mm holes	547182A
Size .35 mm for .375 and .400 mm holes	2478031-1
Pin Vise, Needle Holding	2471052
Indicator, Nozzle Valve Lift	2470451
Arbor, Nozzle Seat Lapping (Set 4)	2471681
Machine, Nozzle Valve and Seat Lapping	2470371
Grinder, Nozzle Valve	2470611
Grinding Wheel	24722010
Sleeve, Centering Nozzle in Cap Nut	2471041
Fixture, Injection Tube Salvage	2474481
Test Stand, Pump Calibrating	2470331-5
Pump, Fuel, Calibrating Kit (Master):	
APFICQ-150T-4016	2470841
APFICQ-150T-4561	2470842
APFICQ-170T-5048	2470848
APFICQ-160T-5655	2470849
APFICQ-180T-6445	24708410
Lapping Compound, for Nitraloy Nozzles (1/4 Lb. Jar)	2474202-1
Tallow, Mutton (1/4 Lb. Jar)	2474204

"DEEP BOWL" PISTON AND CONNECTING ROD ENGINE MODEL 251-PLUS

DESCRIPTION

Piston and Rings

The piston consists of a high temperature resisting steel crown and an aluminum body. The crown is secured to the body by a shrink fit and a properly tightened nut on a centrally located stud.

The piston currently in use with the Bombardier-Alco Model 251-plus engine is of the positive flow, oil cooled, trunk type.

Provision is made for a 5 piston ring arrangement. Three compression rings are carried in the steel crown; two oil scraper rings are carried in the piston body, one above and one below the piston pin.

Drainage holes in the piston body at the oil scraper ring location, allows for the drainage of oil scraped from the cylinder liner walls, back to the engine base.

Piston Pin

The piston pin has a floating fit in the piston and a running fit in the steel backed, bronze-lined connecting rod bushing. A rolled sleeve is installed in the pin bore to seal in the cooling oil. Special snap rings are provided at each end of the pin to hold it in place.

FIGURE 1 – "DEEP BOWL" PISTON

Connecting Rod

The connecting rod (shown in Figure 2) is a high strength alloy steel forging with the conventional rod cap. Pressed into the piston end of the rod is a steel-backed, bronze-lined, split piston pin bushing. The crankshaft end of the rod is provided with upper and lower precision-type coated bearing shells which are held in position by locking tabs. The lower shell has a full groove for lubrication; the upper shell has a partial groove. Joining both ends of the rod is a drilled passage for pressure fed lubrication. The rod cap is aligned to the rod by a short and long dowel and is secured by four bolts and nuts.

Piston Cooling (refer to Figure 3)

Because the piston crown experiences high temperatures during operation, a means of crown cooling is required. lubricating oil is delivered to the piston from the crankshaft for this purpose.

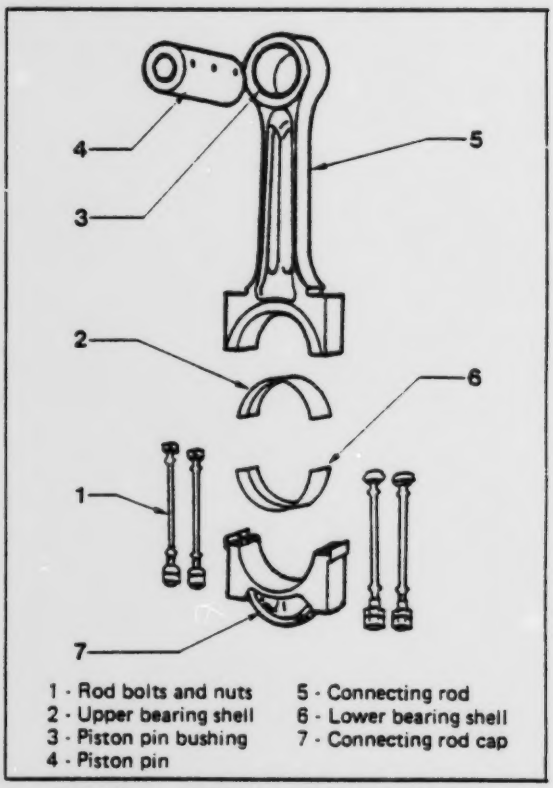


FIGURE 2 – CONNECTING ROD ASSEMBLY

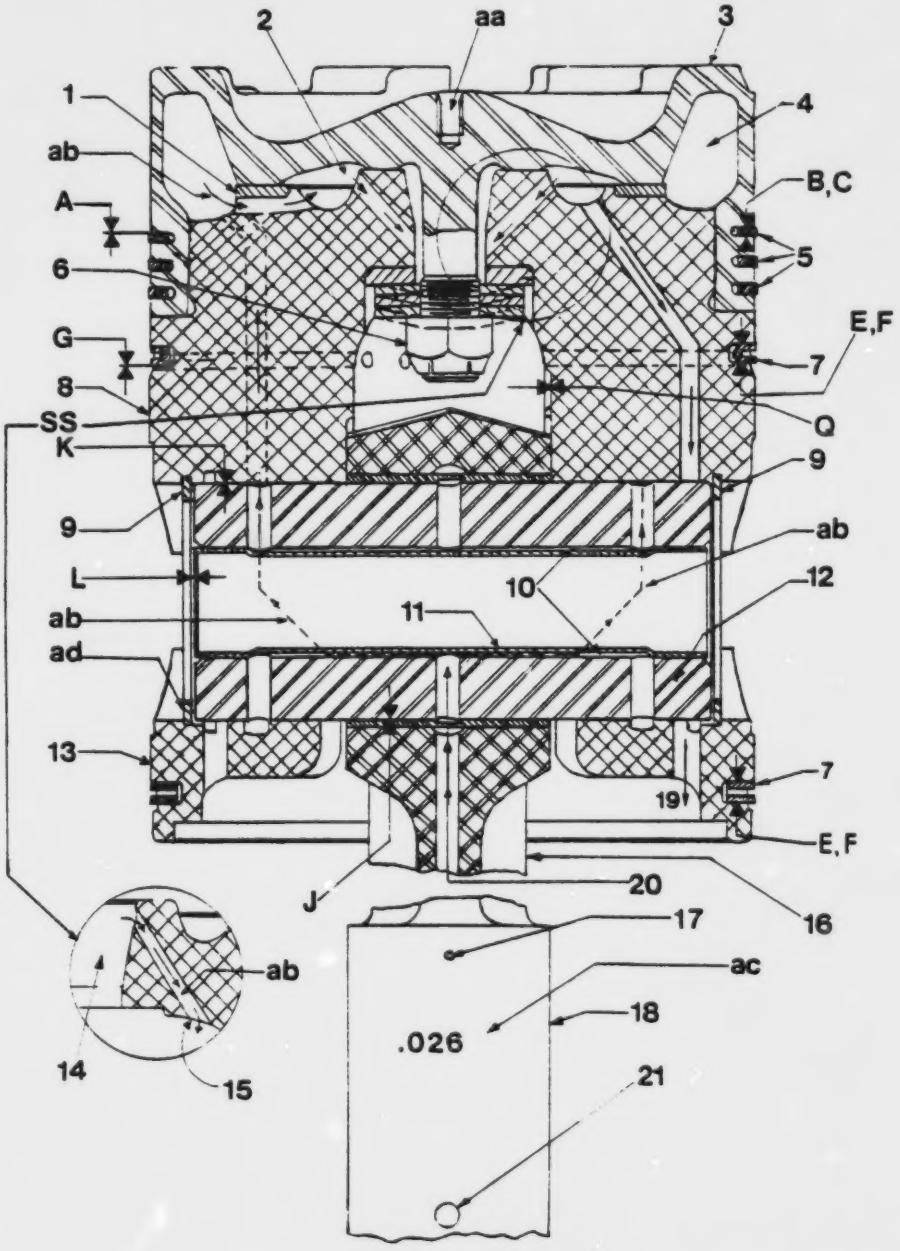


FIGURE 3 – "DEEP BOWL" PISTON ASSEMBLY

INFORMATION FOR FIGURE 3

NOMENCLATURE:

1 - Washer
2 - Inner chamber
3 - Piston crown
4 - Outer chamber
5 - Compression rings
6 - Nut and washer assembly
7 - Oil scraper ring
8 - Piston body
9 - Snap ring
10 - Outer annular chamber
11 - Piston pin sleeve
12 - Piston pin
13 - Piston skirt
14 - Central chamber
15 - Crown cooling oil drain
16 - Connecting rod
17 - "O" orientation marking
18 - Connecting rod foot
19 - Oil drain holes
20 - Oil supply passage in the connecting rod
21 - Long dowel pin location

COMPONENT CLEARANCES, WEAR LIMITS AND DATA

RINGS – STANDARD SIZE:	**NEW**	**LIMIT**
A - Compression Ring Clearance in Groove	0.0050 - 0.0085	0.0120 max.
B - Compression Ring Groove Width	0.1900 - 0.1920	0.1950 max.
C - Compression Ring Thickness	0.1835 - 0.1850	–
D - Compression Ring Gap †	0.0300 minimum	0.2000 max.
E - Oil Scraper Ring Groove Width	0.3140 - 0.3150	0.3165 max.
F - Oil Scraper Ring Thickness	0.3105 - 0.3120	–
G - Oil Scraper Ring Clearance in Groove	0.0020 - 0.0045	0.0060 max.
H - Oil Scraper Ring Gap †	0.0300 minimum	0.1250 max.
PISTON PIN:		
I - Pin Diameter †	3.7490 - 3.7500	3.7475 min.
J - Pin to Bushing Running Clearance	0.0020 - 0.0055	0.0075 max.
K - Pin to Piston Body Bore (room temp.)	0.0005 - 0.0025	0.0035 max.
L - Pin to Snap Ring (total clearance)	0.0760 - 0.1180	–
PISTON TO CYLINDER LINER CLEARANCE: †		
M - At Lower Liner Insert Critical Location		0.0135 min.
CONNECTING ROD: †		
N - Rod-to-Piston Clearance	0.0130 - 0.0240	0.0340 max.
O - Small End Bore (without bushing) (includes ovality of ±0.0005)	3.998 - 3.999	
P - Large End Bore (without shells) (includes ovality of ±0.0005)	6.411 - 6.412	6.413 max.

SPECIAL IDENTIFICATION SYMBOLS AND NOTES:

aa – Threaded hole for piston assembly removal lifting hoist.
ab – Crown cooling, oil flow paths.
ac – 0.026 in. elongation identification marking.
ad – Snap ring gap location.
SS – Piston view rotated 90° from right to left to show central chamber oil drain.

Dimensions shown in inches. † **Not shown in Figure 2.**

The lubricating oil travels from the crankshaft to the piston body by means of a hole through the connecting rod and piston pin (12). The oil enters the outer annular chamber (10) of the piston pin, then passes through two holes in the piston body (8) into the outer chamber (4) of the piston crown (3).

The oil then flows along four grooves under the piston crown spacer ring (1) into the inner chamber (2) where some flows to the central chamber (14), and the rest flows through two drain holes (19) to the base of the piston, and back to the engine base by gravity flow.

DISASSEMBLY

Removal of Connecting Rod Bearing Shells Only

1. Remove crankcase door on each side of cylinder involved.
2. Position the crankpin at approximately bottom center.
3. Remove the nuts (and cotter pins on engines so equipped) and bearing bolts on each side of the connecting rod foot.
4. Remove the connecting rod bearing cap with its lower bearing shell. The cap may be tapped with a soft hammer if necessary.

– CAUTION –

Care should be taken to prevent the cap from falling and possibly damaging the bearing shell.

– WARNING –

The shell must be carefully marked as to location, if it is intended to reuse them. Bearing shells must be replaced in pairs. Reused pairs must be returned to their original locations. Do not mark or write on the bearing face side of the bearing shells.

5. Remove the lower bearing shell from the bearing cap by applying pressure to the side opposite the retaining tang and rolling the shell out.
6. Carefully pry up on the foot of the connecting rod several inches using a wooden wedge and support.

– CAUTION –

Care must be taken to avoid damage to the upper upper bearing shell and shell seating surface.

7. Remove the upper bearing shell from the connecting rod foot by applying pressure to the side opposite the retaining tab and rolling it out.

Removal of Assembly From Engine

1. Drain water from engine block and turbosupercharger. Remove cylinder head and associated piping. See maintenance instructions on "Cylinder Head" and "Jacket Water System" drawing or data for these procedures.
2. Remove crankcase doors on each side of engine.
3. Bar engine over so that crankpin journal for piston being removed is at bottom center and connecting rod bolts and nuts are accessible from both sides of engine.
4. Remove the nuts (and cotter pins on those engines so equipped) and bolts on each side of the connecting rod foot.
5. Remove the connecting rod bearing cap with its lower bearing shell. The cap may be tapped with a soft hammer if necessary.

– CAUTION –

Care should be taken to prevent the cap from falling and possibly damaging the bearing shell.

– WARNING –

The shell must be carefully marked as to location, if it is intended to reuse them. Bearing shells must be replaced in pairs. Reused pairs must be returned to their original locations. Do not mark or write on the bearing face side of the bearing shells.

Rotate the crankpin to the top center position for the piston and rod assembly to be removed.

7. Lift out piston several inches from cylinder using piston lifting device mounted to piston crown and piston lifting hoist (see "Tool List").
8. After piston had been lifted several inches, roll out upper bearing shell from connecting rod by applying pressure to the shell opposite the retaining tab.
9. Remove piston and connecting rod assembly completely, taking care to guide rod through cylinder liner to prevent damage.

– CAUTION –

After removal, the crankpin journal should be wrapped with oil paper to provide protection.

Piston and Connecting Rod Assembly

1. Place piston and connecting rod assemblies on support (see "Tool List") so that rod hangs down between timbers and is supported at foot.

2. Remove snap rings from each side of piston pin with special pliers (see "Tool List").

3. Push pin from piston.

– CAUTION –

It is suggested that two persons accomplish this step.

4. Remove piston from connecting rod.

5. Remove piston rings with expander (see "Tool List").

6. If required, remove bushing from connecting rod by means of press or screw jack, using special arbor (see "Tool List").

7. The sleeve may be removed, if necessary, by machining away the rolled port portion of the sleeve and driving out remainder. Care must be taken not to damage the pin while machining.

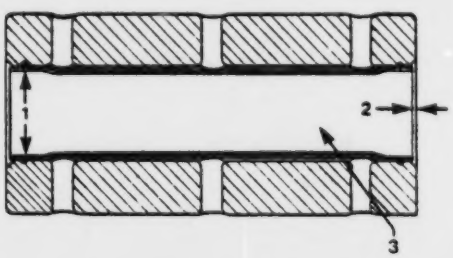
INSPECTION AND MAINTENANCE

Piston Body

After the piston has been cleaned, the outside surface should be examined in order to detect any indication of wear or scuffing.

– CAUTION –

Each piston body must be checked to determine that it does not exceed 8.980 in. dia.



1. 1.655 - 1.665 in. dia. after rolling. Typical both ends.
2. 1/32 in. min. (both sides).
3. Roll sleeve in pin with revolving tube expander after grinding. 0.0005 in. growth of pin O.D. at ends due to rolling permitted.

FIGURE 4 – PISTON PIN

Piston Pin Bore

After the piston has been cleaned, the piston-to-pin and piston-to-connecting rod side clearance should be checked. (See Figure 3).

Piston Ring Groove Wear

After the piston has been cleaned, check the amount of wear at the compression ring grooves. This is done by inserting the outside edge of a new standard size compression ring into each groove in four different positions and measuring the clearance with a feeler gauge. If the clearance between a new compression ring and the ring groove exceeds the condemning limits, a new cap is required. (See Figure 3 for condemning limits, ring and groove sizes).

Piston Rings

Though it is not mandatory, it is generally recommended that the old oil and compression rings be replaced with new ones whenever the piston is removed from the engine.

However, if automatic replacement of the rings is not desired, the rings should be checked and condemned if they are stuck or broken; if they show signs of scuffing or feathering; or if the ring face is not polished for the entire circumference, indicating poor liner contact. These checks can be made while the rings are still in the piston. Once the ring has been removed, it should not be reused since the expansion caused by its removal and subsequent reinstallation distorts it; preventing it from seating properly in the groove and against the cylinder liner.

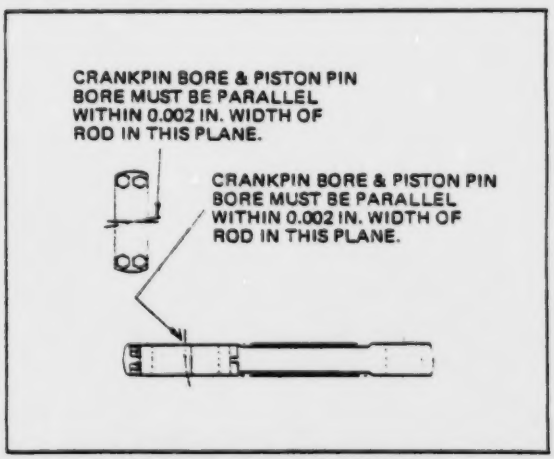

CRANKPIN BORE & PISTON PIN BORE MUST BE PARALLEL WITHIN 0.002 IN. WIDTH OF ROD IN THIS PLANE.
CRANKPIN BORE & PISTON PIN BORE MUST BE PARALLEL WITHIN 0.002 IN. WIDTH OF ROD IN THIS PLANE.

FIGURE 5 – PARALLELISM OF CONNECTING ROD BORES

Prior to installing new piston rings, it is recommended that the ring gap be checked. (See Figure 3 for ring gap limits.) This is done by inserting the ring into a new liner (if available) and measuring the gap with a feeler gauge. This can also be done utilizing the lower unworn portion of the liner vacated by the piston. The ring must be square with the liner bore.

After new rings have been applied, it is not necessary to idle the engine to break-in the rings. Experience has shown that there are no harmful effects resulting from placing the engine in normal service immediately following the installation of new piston rings.

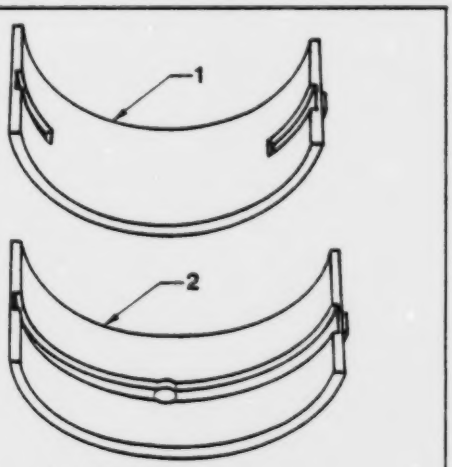
Piston Pin

The piston pin should be cleaned and its surface carefully inspected. If not already done, it is suggested that the sleeve in the pin be removed so that both inside and outside surfaces can be magnafluxed for cracks. If any cracks are detected, the pin should be discarded. (See Figure 4).

Connecting Rod Bolt

To reuse, each bolt must be:

1. Straight within 0.010 TIR.
2. Free of cracks including thread roots by magnaflux inspection.
3. Free of thread galling, distortion and handling damage. Mating nut should turn on freely by hand.



1 - Upper bearing shell
2 - Lower bearing shell

FIGURE 6 – UPPER & LOWER CONNECTING ROD BEARING SHELLS

Connecting Rod

The connecting rods should be cleaned and inspected or magnafluxed for cracks if the equipment is available. It is good practice to magnaflux the rods at each overhaul. Make sure the oil hole drilled in the rod is clear. Use either an air blast or a thin metal rod in order to clear it.

Careful surface inspections of the rods, piston pins and bolts can be made at the same time. Whenever there is any doubt, the parallelism between the crankpin and piston pin bores should be checked. This should not exceed the amount stated in Table 1. A dial indicator and surface plate should be used for this purpose. (See Figure 5, See "Tool List" for checking fixture.)

– NOTE –

A dial indicator reading of 0.00512 is the equivalent of the 0.002 limit, in the horizontal plane, shown in Figure 5 and Table 1.

Bearing Shells

The bearing shells should be cleaned and inspected. If any of the following conditions are noted, the shells should be discarded.

1. Embedded dirt particles.
2. Evidence of fatigue failures.
3. Lead-tin overlay and nickel barrier worn through and copper-lead intermediate layer can be seen. (See Table 1 for running clearance and condemning limit).

If the bearing shell has been examined and found satisfactory, it must be returned to its original position in the engine during reassembly.

– WARNING –

Under no circumstances should a used bearing shell be reapplied to other than its original position.

As shown in Figure 6, the lower bearing shell has a continuous oil groove; while the upper shell has two short grooves on its sides.

Thorough investigation has shown that most bearing shells which have lost free spread through normal stress relieving action during the engine operation will seat firmly against the back of the rod bore when the bolts are properly tightened to the recommended stretch or elongation values. This return of the shells to proper seating is brought about by the normal crush imposed on the shells in a properly tightened rod.

TABLE I

CONNECTING ROD	NEW	LIMIT
Parallelism Between Bores		
Horizontal Plane	–	0.0020
Vertical Plane	–	0.0020
BEARING SHELLS		
Running Clearance	0.0040 - 0.0080 (measured in vertical direction)	When overlay wears through to show intermediate layer.
Out-of-Roundness	–	Horizontal - 0.003 larger than vertical dimension.
Vertical ID	6.0035 - 6.0061	–
Horizontal ID	6.0035 - 6.0086	–

There will be occasional cases where a bearing shell has been abused by rough handling, and as a result, has become kinked. If this is the case, no attempt should be made at correcting the situation by overtightening or mechanical straightening. Also, bearing shells that have been subjected to excessive thermal or mechanical stresses should be discarded.

If there is any question that the proper bearing contact cannot be obtained, the shells should be checked as follows:

1. Coat rod bore and cap with bluing.
2. Assemble rod and cap (with shells) on bench.
3. Apply nuts and bolts and tighten to proper bolt elongation. (See Step 14 of "Installation" in these instructions.)
4. Dissassemble. If bluing was not transferred around entire back surface of shells, complete contact is not being made and shell should be discarded.

If a new bearing shell is being installed, mark it with the same location as was on the old shell, using an electric pencil. Identification marks are made on all shells to determine proper location. A new shell may be installed as a mate to an old one, provided the old one is not worn beyond its condemning limit and provided it remains in its original position. Once shells have established their bearing surfaces, do not mix them up.

Examine and remove any nicks or burrs from the bearing shells before application. Do not file, scrape or sand on the bearing surface. Nicked or badly scratched bearing shells (bearing side) should be discarded. The bearing shells should be checked for out-of-roundness in the following manner.

1. Assemble clean rod and cap (with shells) on bench.
2. Apply nuts and bolts and tighten to proper bolt elongation. (See Figure 3 and Table 1.)
3. Measure ID of rod bore across horizontal and vertical planes.
4. If horizontal measurement exceeds vertical by amount stated in Table 1, bearing shells are out-of-round.

Piston Pin Bushing

The piston pin bushing is pressed into the small end of the rod with the bushing flush on both sides of the rod. At overhaul periods the wear should be carefully checked. The clearance between the piston pin and bushing should not exceed the limit specified in Figure 3. If the clearance limit has been reached, renew the bushing.

The piston pin bushings may be installed as a replacement in any of the rods as they are completely interchangeable. However, when a bushing is installed as a replacement, it is recommended that the piston pin be used as a spotting mandrel for checking the bore in the bushing. Feeler gauges should also be used for checking clearance between the pin and the bushing.

REASSEMBLY

Piston and Connecting Rod Assembly

1. Thoroughly clean and coat all parts with clean lubricating oil.

2. Using spinning tool set (see "Tool List"), apply sleeve to piston pin in following manner:

   a) Place pin in holding fixture.

   b) Insert new sleeve in pin bore.

   c) Place depth plug in sleeve and press until flange on plug contacts pin.

   d) Remove plug; insert expander in sleeve and roll it until roller stop strikes sleeve. (See Figure 4.)

   e) Remove pin from fixture, invert and repeat Steps "c" and "d" for other end of sleeve.

3. If previously removed, press bushings into connecting rod, using special arbor (see "Tool List").

– CAUTION –

Be sure to align the large oil hole in the bushing with the oil hole in the connecting rod before assembly. Recheck alignment after the bushing has been applied.

4. Place the piston upside down on a bench.

5. Position the piston such that the dimple at the bottom of the piston skirt, indicating fuel pump side, it to the right.

6. Lower the connecting rod into the piston body such that the "O" stamped on the connecting rod leg aligns with dimple on the piston.

7. Align the rod bore with the piston pin hole and apply the piston pin to the piston.

8. Using special pliers, apply snap rings to piston. Make sure that snap ring gaps are at bottom center.

9. Using special lifting device mounted on head of piston, lower piston and rod assembly onto support so that rod hangs down between timbers and is supported at foot (see "Tool List").

10. Apply new piston rings (see applicable DRP), using a ring expander.

– CAUTION –

All compression rings should be applied with pit marks up. Scraper rings (which have sharp edges to remove excess oil from cylinder liner on downward stroke) should be applied with sharp edges facing down. Care should be taken not to expand rings more than necessary as overexpansion may cause permanent distortion.

– NOTE –

On marine application, the upper scraper ring is a conformable ring which is equippped with coil spring expander to make it conform to liner surface as it wears. Be sure joint in coil spring is 180° from gap in ring.

Installation in Engine

– WARNING –

Be sure the markings on the bearing cap and lower bearing shell correspond with those of the upper bearing shell and connecting rod. Bearing caps and connecting rods are not interchangeable. If new bearings are being installed, mark accordingly with an electric pencil. If bearing shells are reused, they must be returned to their original locations.

1. Apply piston lifting device to piston crown if not previously applied.

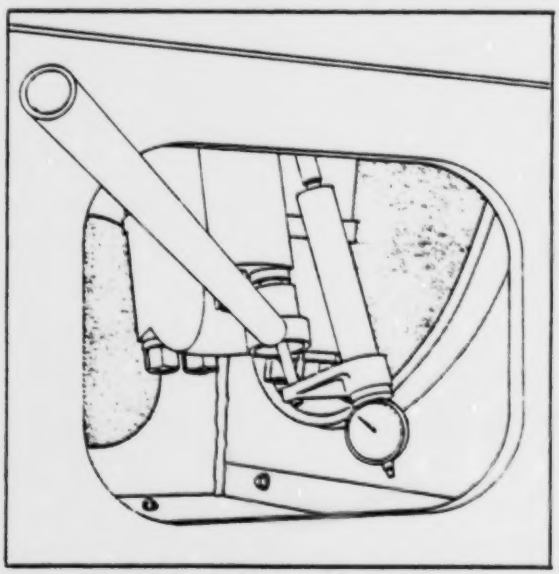


FIGURE 7 – ELONGATION GAGE AND SOCKET WRENCH IN TIGHTENING POSITION IN ENGINE CRANKCASE

2. Arrange rings on piston so that adjacent ring gaps are 180° apart.

3. Coat piston and rings with clean lubricating oil.

4. Remove paper covering from crankpin journal. Oil journal and insides of bearing shells with clean lubricating oil.

– CAUTION –

Prior to installation, cylinder liner must be first checked to see if top compression ring has caused ridge to form on liner. Breakage of new ring could result if ridge is not removed. (See maintenance instructions on "Cylinder Liner" for correct ridge removal procedure.) Following removal of ridge, be sure liner is cleaned and lubricated.

5. Apply ring compressor to cylinder liner.

6. Bar engine over so that crankpin journal for piston being installed is at bottom center.

7. With piston lifting hoist, lower piston and rod assembly through ring compressor and into cylinder, such that the "O" stamped on the connecting rod foot is toward the outboard side of the engine.

– CAUTION –

Be sure to guide the connecting rod foot through the cylinder liner to prevent damage to the liner.

8. When the connecting rod foot is within 4 in. of the crankpin, roll in the upper bearing shell, making sure the locking tab in the bearing shell fits into the groove in the connecting rod foot.

– CAUTION –

Be sure to install the proper bearing shell. (See Figure 6.)

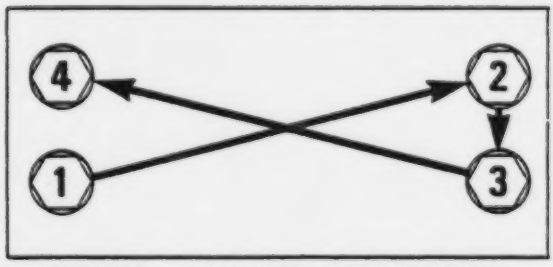


FIGURE 8 – BOLT ELONGATION SEQUENCE

9. Continue to lower piston and rod assembly until the connecting rod bearing contacts the crankpin.

10. Roll the lower bearing shell into the connecting rod bearing cap, making sure the locking tab in the bearing shell fits into the groove in the connecting rod bearing cap.

11. Apply the bearing cap to the connecting rod such that the "O" stamped on the bearing cap is on the same side as the "O" stamped on the foot of the connecting rod.

12. Coat the bolt threads and nut faces with anti-seizing compound (see "Tool List").

13. Apply the connecting rod bolts to the connecting rod from the top, with the bolt heads butted together.

14. Apply the connecting rod bolt nuts and run up finger tight.

15. Tighten the connecting rod bolt nuts to 0.026 in. elongation in the following manner.

– NOTE –

The connecting rod foot will have the markings "0.026". If your connecting rods do not have this marking, consult your Bombardier-Alco Service Representative before proceeding.

a) Refer to Figure 7 and install the connecting rod bolt elongation tool and wrench as shown.

b) Tighten all four bolts to an initial elongation of 0.015 in. +0.003 in. in the sequence shown in Figure 8.

c) Starting again with Number 1 (see Figure 8), loosen one bolt and set elongation gauge to zero. Stretch bolt to final elongation of 0.026 in. +0.001 in. Repeat procedure for remaining three bolts in sequence shown in Figure 8.

d) Check piston to cylinder liner clearance as per Figure 3.

16. Reapply the crankcase doors on each side of the engine.

17. Refer to the "Cylinder Head" publication and reapply the cylinder head.

18. Refill the engine cooling system in accordance with the "Water Treatment" publication.

TOOL LIST

Item	Catalogue Number
Adapter, Piston Pin Hole (for cleaning)	2478172
Anti-seizing Compound (1 pint)	21559334
Connecting Rod Checking Fixture	2472682
Connecting Rod Mandrel Kit (required with checking fixture)	2472584
Elongation Gage with Wrench	2470048
Elongation Gauge	2470145
Socket Wrench	24720613
Indicator with Magnetic Base	2478005
Piston and Connecting Rod Lifter	2478192
Piston Pin Bushing Arbor	2471682
Piston Ring Inserting Tool	2471268
Piston Ring Expander	2479391-4
Piston and Connecting Rod Support	2471331
Piston Lifting Hoist	2470095
Support (locomotive only)	2470704
Pliers for Snap Ring	2479621
Plug, Piston Pin Hole (for cleaning)	2478173
Spinning Tool Set, for Rolling in Piston Pin Sleeve	2471924-1
Fixture, for Holding Piston Pin	2478771
Expander	2478762
Positioner	2479972

See also: Bombardier-Alco Model 251 Tool Catalog.

CYLINDER HEAD

DESCRIPTION

The cylinder head, shown in Fig. 1 is secured to the cylinder block by seven studs. Individual water jumpers from the cylinder block to each cylinder head conduct water from the cylinder block to water cooling passages in the cylinder heads. The cooling water discharge from each head is carried to the water outlet header by individual elbow connections.

Cored passages permit the admission of scavenging air and the expulsion of exhaust gases.

Metal-to-metal joints of the flat lap type form the gas seal between the cylinder heads and cylinder liners and prevent the escape of gases from the cylinder. No gasket is required between cylinder head and liner.

Each head has chambers for two 30° air inlet valves, two 45° exhaust valves and a fuel injection nozzle.

The valve lever bracket assembly, consisting of a bracket and two valve levers mounted on a valve lever shaft, is applied to the top of the cylinder head along with the equalizing yokes. Refer to "Valve Lever Mechanism" publication. The valve mechanism assembly and fuel injection nozzle on top of the head are enclosed by a steel cover.

DISASSEMBLY

Removal from Engine

1. Drain engine water.
2. Remove valve lever casing.
3. Remove valve lever assembly from cylinder head.
4. Lift out pushrods.
5. Disconnect air inlet and exhaust elbows.
6. Disconnect and remove fuel oil drain line.
7. Disconnect and remove lubricating oil supply line to valve operating mechanism.
8. Disconnect and remove high pressure fuel line and nozzle.
9. Remove water inlet jumper and water outlet elbow.
10. Remove cylinder head nuts and lift off head using lifter.

Valves and Valve Guides

1. Rest cylinder head on a wooden bench with circular wooden plate positioned so as to keep valves closed and to protect cylinder head seat.
2. Using valve spring depressor, compress valve spring until spring lock holding valve spring to spring seat is free.
3. Remove spring lock.
4. Release valve spring depressor and remove valve spring and spring seat.
5. Turn head on side to remove valves.

– NOTE –

Valve guides can be removed by pressing or driving them out from bottom of head. Removal is necessary only when guides are worn or damaged.

Valve Spring Removal with Head in Place

In case it is desirable to replace a valve spring without removing the cylinder head, the piston of the cylinder involved should be brought to top dead centre. Remove the valve lever assembly. Using the valve spring depressor, remove the spring lock and spring. Apply a new spring; compress and apply lock.

Equalizing Yoke Guides

Two equalizing yoke guides are pressed into the cylinder heads. The guides are threaded so that they may be removed with a yoke guide puller, if the clearance between the yoke and guide becomes excessive, or if the yoke guide becomes bent.

Nozzle Hole Sleeve

1. Clean nozzle hole with cylinder head nozzle hole cleaning tool.
2. If necessary, remove nozzle hole sleeve with sleeve extractor (see "Tool List").

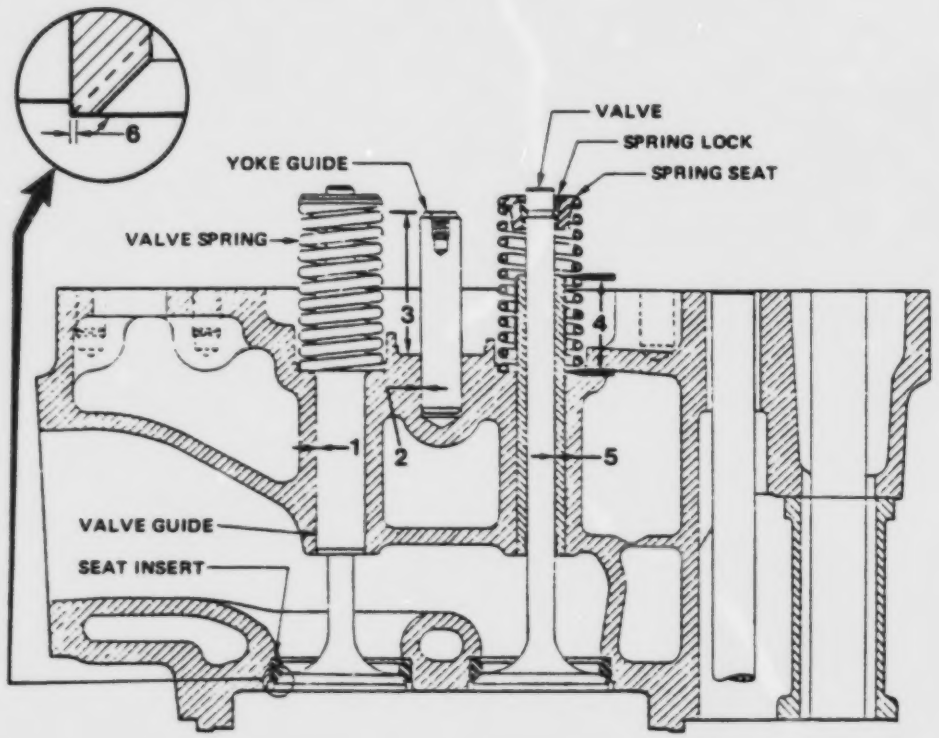


TABLE OF CLEARANCES AND TORQUE VALUES

1. Valve guide to head . 0.0020 to 0.0005 in.dia. int.

2. Yoke guide to head . 0.0005 to 0.0020 in.dia. int. metal to metal

3. Yoke guide (press into dimension) . . . . . 3.210 to 3.272 in. (exh.) 3.195 to 3.257 in. (air)

4. Valve guide (press into dimension) . . . . . 2.25 in.

5. Valve to guide clearance:
   Type C or F valve:
   (New) top . . . . . 0.0030 to 0.0045 in.
   (New) bottom . . . . . 0.0050 to 0.0065 in.
   Condemning . . . . . see Fig. 8

5. Valve to guide clearance (cont'd):
   Type E valve:
   (New) straight . . . . . 0.002 to 0.004 in.
   Condemning . . . . . see Fig. 8

6. After grinding valve seat, machine back its face as shown to give 1/32 in. minimum flat.

TORQUE VALUES:
Cylinder head nuts . . . . . 550 ft.lbs.
Water inlet elbow screws . . . . . 75 ft.lbs.

DIFFERENCES IN VALVE TYPES ARE SHOWN IN FIGURE 2

FIGURE 1 – CYLINDER HEAD CROSS SECTION AND DIMENSIONS

INSPECTION AND MAINTENANCE

Water Test

Hydrotest cylinder head for leaks at 70 PSI with 190°F water temperature. Cracked heads should be scrapped. See "Cylinder Head Test Stand" publication for the correct method of testing.

Valves, Valve Seat Inserts and Valve Guides

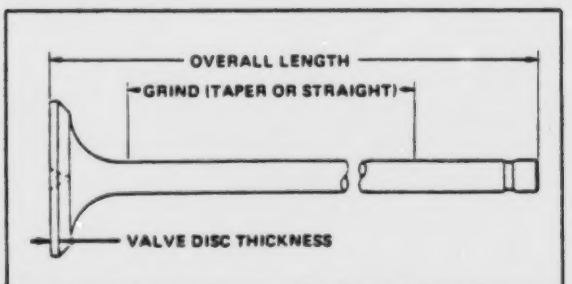
Unless extreme caution is used while grinding the valve seat inserts, valve seat cracking may result. A major cause for this condition is either the use of improper stones or the application of too much pressure on the driver when grinding the seat.

If it is necessary to remove a valve seat insert, use a valve seat extractor tool. After removal, inspect bore for damage. Check bore diameter to determine if it is necessary to machine the bore for an oversize insert. If the bore is within the standard dimension shown in Fig. 3, a new standard size insert may be applied without additional machining.

Machining Insert Bores

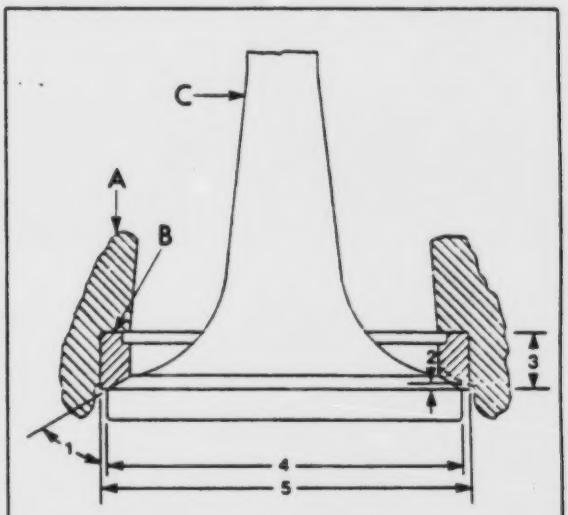
The procedure for machining bores for oversize inserts is as follows:

1. Remove all valve guides, equalizing yoke guides and studs.
2. For standard oversized valve seat inserts, machine cylinder head bore to dimension indicated in Fig. 3.
3. Blow out chips.
4. Press in new valve guides, using inserting sleeve tool.
5. Press in new valve equalizing yoke guides (used ones may be reinstalled if within limits shown in Fig. 1).
6. Apply new nozzle studs or reapply old studs if in good condition.



Valve type	Valve stem	Overall length inches	Part number	Face angle	Valve disc thickness	
					New	Condemning limits
"C"	0.004 taper grind	11-1/2	2231129	45°	0.1562 in.	0.0625 in.
"E"	straight grind	11-1/2	22311211	30°	0.1750 in.	0.0937 in.
"F"	0.004 taper grind	11-1/2	22311210	45°	0.1562 in.	0.0625 in.

FIGURE 2 – THREE TYPES OF VALVES



A-Cylinder head B-Valve seat insert C-Valve

References	Type 1 - 45° (exhaust)	Type 2 - 30° (air)
1- Angle of valve seat insert chamfer	44-1/2°	59-1/2°
2- Maximum allowable wear step at valve seat insert chamfer before regrinding	0.031"	0.031"
3- Valve seat insert thickness (new)	0.532"	0.565"
4- Valve seat diameter – new (on insert)	2.938"	3.030"
5- Valve seat insert bore:		
Standard size	3.1805-3.1815"	3.1805-3.1815"
First standard oversize	3.1905-3.1915"	3.1905-3.1915"

NOTE: Concentricity of valve seat insert with valve guide bore must be within 0.002" for Type 1 and within 0.003" for Type 2.

FIGURE 3 – VALVE AND VALVE SEAT INSERT TOLERANCES

Application of Inserts

The tools required for the application of inserts are: an inserting sleeve, a plug and a guide. It is necessary that proper size inserting sleeve be used when applying the different size inserts. Apply inserts as follows:

1. Place insert in inserting sleeve tool and cool in dry ice.
2. Cylinder head must be heated uniformly by steam or hot water to approximately 200°F.
3. At assembly, there should be 250°F temperature difference between the head and valve seat insert.
4. Apply guide rod tool into bore of valve guide.
5. Remove insert and sleeve assembly from dry ice and place squarely into insert bore. Apply plug into inserting sleeve and around guide rod tool.
6. Holding inserting sleeve firmly in place, push valve seat insert into the bore of head by using press on plug until insert is bottomed against head. Do not hammer into position. Keep hand pressure on valve seat insert for 30 seconds while insert expands into place.
7. After tools are removed, check with 0.0015 inch thickness gauge to determine that there is no clearance between insert and bottom of bore. If insert is cocked in bore, or not firmly seated, it should be removed and new insert applied.

Application of Valve Guides

1. Press in new valve guides with inserting sleeve tool, in accordance with the dimension shown in Fig. 1.
2. Check that the valve guide bore dimension is 0.622 in. diameter by passing a 0.622 in. arbor.
3. If the 0.622 in.dia. arbor does not pass easily through the valve guide bore, check the interference fit between valve guide and cylinder head. Normal limits are 0.0005 in. to 0.002 in. interference. Select another guide and apply. Recheck with arbor until correct.

– NOTE –
Do not attempt to ream the valve guide because of the hardness of the metal.

4. All valve guide bores should be cleaned using a 5/8 in. diameter wire brush. The brush has a spindle which may be attached to a hand drill or some other hand machine.

Valve and Valve Seat Grinding

In addition to the apparatus required to grind valve seats, a supply of Turco "Dy-Check" fluid should be available for use in detecting surface cracks.

The procedure for grinding valve seat inserts and reconditioning valves is as follows:

1. Remove glaze on valve seat by placing piece of sandpaper under grinding stone and then spinning stone. Should seat be bad, use a reamer. Turning it slowly with air motor.
2. Grind seat. Use dial indicator to check the trueness. Weight of grinder should be only pressure exerted on insert during grinding. Dress stone frequently at angle specified in Fig. 3 to eliminate formation of glaze on stone.
3. Check valve seat run-out. The concentricity with valve guide bore must be within tolerance indicated in Fig. 3.
4. Check surface of valve seat insert with "Dy-Check" for cracks.
5. Valve faces should be checked for cracks. Valves showing cracks should be scrapped.

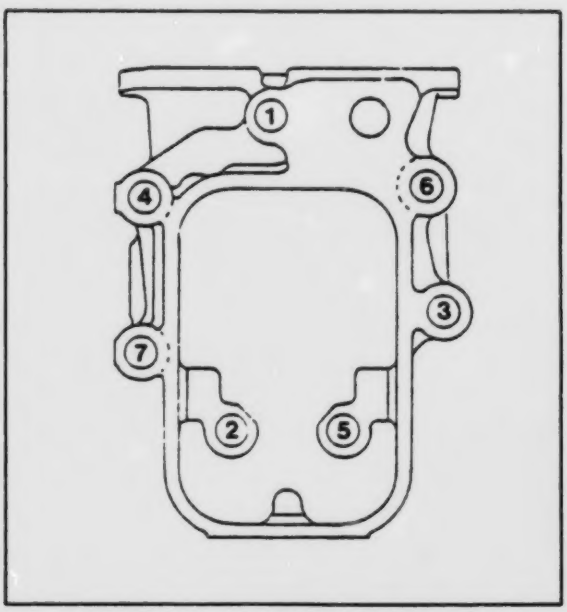


FIGURE 4 – CYLINDER HEAD NUTS TIGHTENING SEQUENCE

6. Valves should also be scrapped when disc thickness is beyond limits stated in Fig. 2.

7. Valves should be faced at 45° and 30° respectively.

8. To check valve with seat, blue valve, insert in valve guide and bounce against valve seat. Fine blue line must show around entire circumference on large diameter of seat contacting area.

9. Valve seat limitations should be followed as recommended in Figs. 3 and 5.

Compression Seal

Since the cylinder head to liner joint is metal-to-metal, the seating area must be in good condition. These surfaces should be checked and if necessary, lapped using a lapping ring. See "Inspection and Maintenance" in "Cylinder Liner" publication. Sealing surfaces must be smooth and in one plane. Using bluing, a continuous blue mark not less than 1/16 in. wide must show throughout the circumference.

– CAUTION –

Machining of fire deck is not allowable.

Nozzle Hole Sleeve

A sleeve is applied with Tite-Seal N° 2 (non-hardening) in the nozzle hole of each cylinder head to provide a water jacket for nozzle cooling and to furnish a seat for the nozzle.

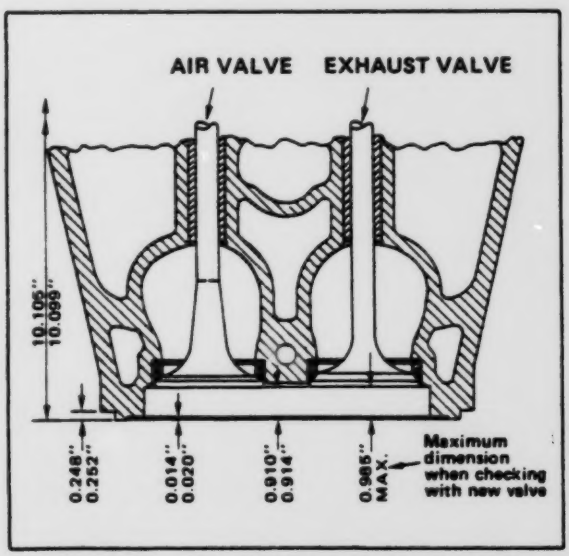


FIGURE 5 – CYLINDER HEAD WEAR LIMITS

If a water leak should occur between the sleeve and head, it is suggested that the old sleeve be first rerolled and the head water tested before applying a new sleeve. However, if it is necessary to install a new sleeve, it should be renewed according to instructions under "Disassembly" and "Reassembly".

Valve Spring

In order for a valve spring to give satisfactory service, the spring load must not be less than 118 pounds at a spring height of 3-13/16 in. for spring Part No. 2461082-1, and 123 pounds at a spring height of 3.670 in. for spring Part No. 2461086.

REASSEMBLY

Nozzle Hole Sleeve

1. Coat seating surfaces of new sleeve with Tite-Seal or equivalent and enter sleeve in nozzle hole, tapping it down until sleeve bottoms firmly in head. (See Fig. 6).

2. Insert holding device and tighten nut until nozzle sleeve is held firmly in position at lower seat.

3. Using nozzle hole sleeve tube expander, roll in upper portion of sleeve.

4. Remove holding device. With sleeve tube expander, roll in lower portion of sleeve.

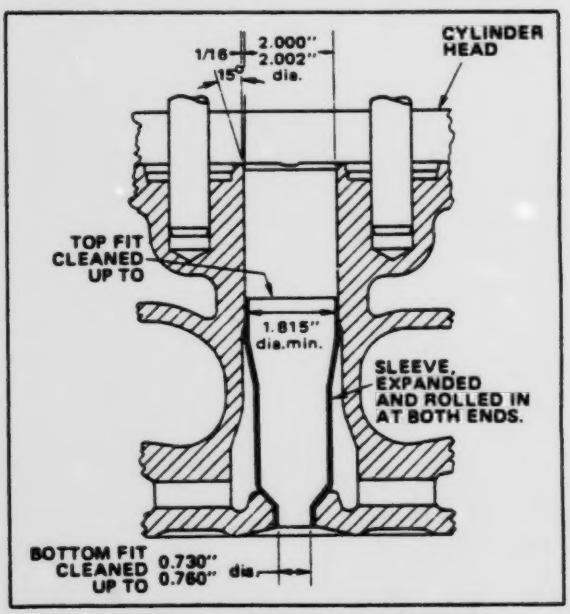


FIGURE 6 – NOZZLE HOLE SLEEVE

5. Air test the cylinder head at 85 PSI while submerged in 120°F water.

Valve and Valve Guides

1. Press in new guides.
2. Turn head on its side and insert valves. Then place head on a block of wood to hold valves up in place.
3. Place valve springs over valve stems and set spring seats on top of springs.
4. Using valve spring depressor, compress spring until grooves in valve stems are exposed. Apply spring locks and release valve spring depressor.

Equalizing Yoke Guides

Apply white lead to guide and press into cylinder head.

Installation on Engine

1. Before installing cylinder head, clean compression seal joint faces of cylinder head and liner. Clean gasket seating surfaces of head and block.
2. Install the two pushrod housings after applying silicon to their seating surfaces.
3. Insert grommets in pushrod holes in cylinder block (if removed).
4. Set head in place and align with straight edge. Squaring heads with a straight edge assures proper alignment of bolt holes in air and exhaust elbows.

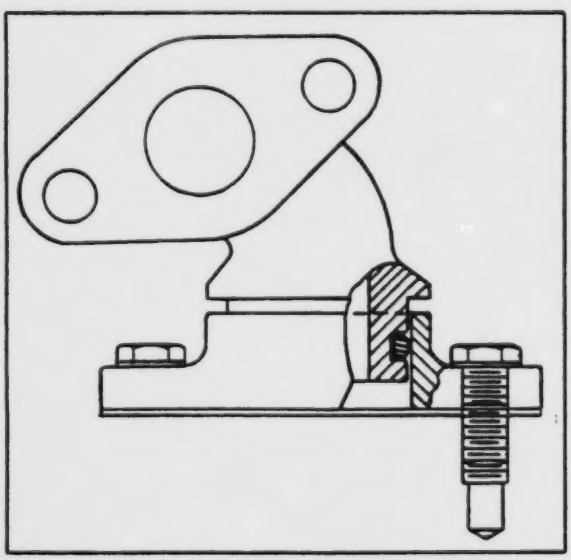


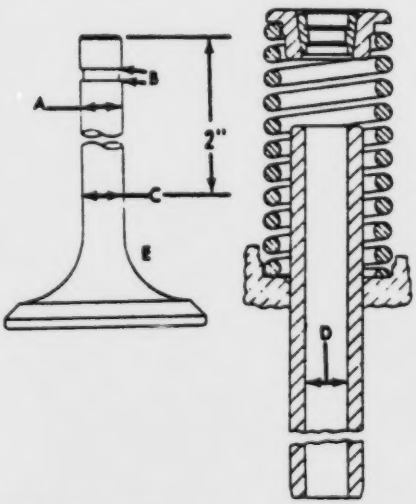
FIGURE 7 – WATER INLET ELBOW

5. Apply a light coating of graphite grease to the threads of all studs. Install all nuts and hand tighten. Refer to Fig. 4 (Cylinder Head Nut Tightening Sequence). Starting with N° 1 as per illustration, tighten nuts in sequence shown; snugging each nut to 40 ft.lbs. using a torque wrench.

– CAUTION –

Do not use impact wrenches. Check clearance between cylinder head and liner at six points with thickness gauge to determine if head is being drawn down evenly.

6. Repeat tightening sequence as called out above in steps to 100, 300, and 550 ft.lbs., making certain that the final torque of 550 ft.lbs. is not exceeded.
7. Connect air inlet and exhaust elbows. Refer to "Exhaust Manifold" and "Air Elbow" publications for instructions on making connections.
8. Apply fuel oil drain pipe.
9. Apply water inlet elbow. Gaskets are used top and bottom. (See Fig. 7.) All capscrews are to be tightened evenly. See Fig. 1 for torque value.
10. Apply lubricating oil supply line to valve operating mechanism.



A- 0.6205-0.6195 dia. (new).
B- 0.025-0.031 radius. Replace valve is these radii are sharp or stem is bent.
C- 0.618" minimum diameter.
D- If valve guide ID exceeds 0.626" measured 1 in. from end of guide not counterbored, guide should be replaced.
E- Replace if stem is scored or if wear step exceeds 0.0025.

FIGURE 8 – VALVE & GUIDE ASSEMBLY

11. Apply water outlet elbow. Refer to "Water Outlet Header" publication.
12. Check that injector stud height taken from the top of the cylinder head is 4-5/16 ± 1/16 in.
13. Apply fuel injection nozzle and holder assembly. Make sure that pin in nozzle holder is in aligning slot in cylinder head.
14. Apply nozzle retaining clamp so that center of clamp bearing surface is directly over centreline of nozzle holder. Tighten clamp nuts hand tight until the clamp is parallel to the head surface.
15. Apply fuel injection pipe to nozzle holder using snubber valve at pump. Make sure that mating surfaces between pipe and nozzle are absolutely clean and properly aligned.

– NOTE –

Refer to "Fuel Injection Nozzle and Holder" publication.

16. Apply pushrods and valve lever mechanism.

VALVE SEAT GRINDING INFORMATION

Item	Part No.
"Sioux" grinder:	
45° stellite inserts:	
Fine stone	24722029
Coarse stone	24722030
30° Stellite inserts:	
Fine stone	24722032
Coarse stone	24722033
"Hall Toledo" grinder:	
45° stellite inserts:	
Fine stone	24722024
Coarse stone	24722023
30° stellite inserts:	
All purpose stone	24722031
PILOTS	
"Hall Toledo"	24722118
"Sioux":	
Pilot diameter:	
0.6225 in.	24722125
0.6235 in.	24722126
0.6245 in.	24722127
0.6255 in.	24722128

TOOL LIST

Item	Part No.
GUIDE, VALVE	
Brush	2474062
Brush holder	2478062
Brush holder extension	2472083
Cleaner	2479561-1
Puller	2472021
Sleeve, inserting	2471382-1
SLEEVE NOZZLE	
Expander, bottom	2474154
Expander, top	2474153
Extractor	2471432-1
Holder	2471433
Reamer, nozzle seat cleaning	2473032-1
VALVES	
Depressor, spring, manual	2471414-1
Valve retainer (for use with depressor)	2479493
Depressor, spring, pneumatic	2470632
Grinder, valve face (plus special equipment as required)	2470211
INSERT, VALVE SEAT	
Extractor	2470896
Insertor	2470852
Grinder (Hall-Toledo)	
Basic set (110 Volts)	2470223-1
Basic set (220 Volts)	2470224-1
(plus special equipment as required)	
Grinder (Sioux)	
Basic set (110 Volts)	2470225
(plus special equipment as required)	
HEAD, CYLINDER	
Expander, bolt hole sleeve	2474152
Compression pressure:	
Adapter	2370014
Gasket - Adapter to cylinder head	2151119
Indicator:	
Dual and straight fuel	24780010
Lifter attachment	2471282
Ring, seat lapping	2471422
Wrench, power (reduction)	24701913

In process. Will be forwarded when available.

TORQUE VALUES

WEIGHT TO BALANCER SHAFT

Capscrew, socket head, 3/4 - 10 x 3 in. ..... 100-110 ft.lbs.

BLOCK TO BASE

Nut, 1-1/2 - 6 NC - 2B ..... 1460 ft.lbs.

Nut, 1 - 8 NC - 2B ..... 480 ft.lbs.

BEARING CAP TO BASE

Stud Bolt, bearing cap ..... Stretch to 0.040 in.

Data subject to change without notice.

Publication No. 79 Issue 1 (12.80)

Bryce

Service Instructions for CV size Pumps

Type FCVAB

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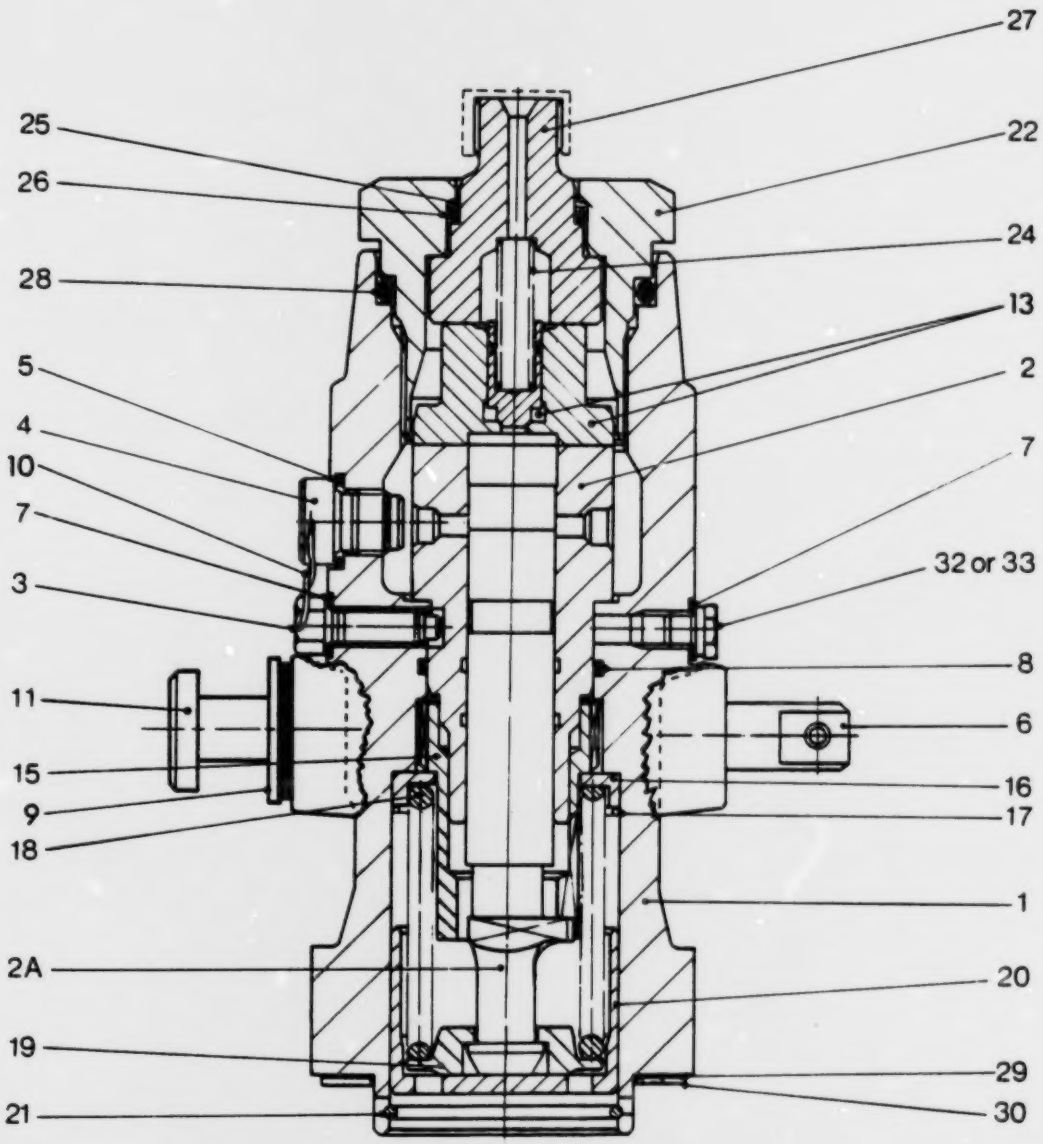
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Figure 1

To cater for the requirements of the new generation of more highly rated engines the CV pump has been introduced.

This pump, shown in figure 1 is based on extensive experience gained with the CC pump, and provides within the same installation envelope a very robust pump having 50% greater output and pressure capability.

It is suitable for operation on residual fuels up to 1500 sec Redwood No 1, and provision can be made to lubricate the element and the lower working parts from the engine lubrication system.

The lubricating oil pressure must always be at least 1 bar higher than the fuel inlet pressure to prevent migration of fuel to the lubricating oil.

For the same reason a simple non-return valve is used so that fuel cannot enter the lubricating system when the engine is stationary.

INTRODUCTION

The Bryce CV-size fuel pump will normally have a long working life before requiring overhaul and replacement of parts, provided that the fuel oil and engine lubricating oil have not been contaminated by dirt or water, and that where residual fuel is used, the correct preheat temperature and procedure for changeover are adhered to.

Failure to meet these requirements can result in premature wear, corrosion, leakage or component failure, and may also be detrimental to the injector, and to the engine itself. The only adjustments possible are of injection timing, and output calibration.

The need to remove pumps for overhaul or adjustment will be indicated by the Engine Manufacturer's recommended servicing schedules, backed up by operating experience, and will vary according to the rating, operating environment and type of duty. It is thus only possible to give general advice within the scope of these instructions.

Fuel pumps will wear with time, but such wear is usually uniform throughout an engine set, so that balance between pumps will remain acceptable for normal operating requirements.

The degree of wear, particularly of the elements, may be judged by comparing the control rod settings at full load with those recorded on the original engine test sheets. As a general guide, fuel pumps should be removed for examination when the control rod setting has increased by 10%. The requirement to increase settings to maintain full load normally indicates an extending injection period, which will be accompanied by rising fuel consumption and exhaust temperature.

Individual pumps which behave differently from the remainder of the engine set should be examined as soon as possible.

A pump requiring a high control rod setting to balance exhaust temperature may have a worn element, or leaking delivery valve; running hot can result from leakage from the high pressure joint, possible causes being restriction in the high pressure line (blocked spray holes or filter, inadequate needle lift, damaged pipe, or insufficiently preheated residual fuel).

Intermittent delivery, or no delivery, may be due to a sticking or seized element particularly if the control rod is stiff to move or jammed, or to a broken plunger spring.

Abnormal leakage of fuel oil from the base of the pump will usually be due to element wear, which may have its origin in water in the fuel.

Notes are included in the section on Examination of Components for guidance in assessing component condition, and fault diagnosis.

DISMANTLING

When preparing to dismantle fuel injection equipment, the bench on which the work is to be done should be cleaned thoroughly, particular attention being taken to remove all dirt, grit, metal filings and other foreign matter.

Provide a number of clean trays or similar containers for the components. Have available a clean vessel containing clean fuel oil for washing the dismantled parts.

The use of Kerosene (paraffin) is not recommended for washing parts as it may contain water which can cause corrosion.

During dismantling operations, the components from each individual pump should be kept separate. It is essential that pump plungers are only refitted to the barrels to which they were originally mated, similarly the delivery valve thimble should only be reassembled to its original seat.

When overhauling pumps, the plungers, barrels, delivery valves and seats should never be touched with a file or other hard tool. If any of these parts are damaged the assembly should be sent to a Bryce Service Agent for attention.

Before starting to dismantle a pump, remove protection plugs or caps if fitted, and pour off any fuel oil which may remain in the pump.

PROCEDURE. LOWER END

Refer to figure 1
Mount the pump vertically, flange uppermost, in a vice fitted with smooth or soft jaws, and grip it by the flats of the retaining nut.

Depress the tappet (20)clear off the lower circlip (21), and push a steel rod 3–4 mm diameter through one of the radial holes in the spigot to displace the circlip (21) from its groove.

Prise out the circlip using a small screwdriver, withdraw the steel pin and lift out the tappet. **Note.** The tappet can be depressed sufficient for circlip removal using the wooden handle of a hammer, and the steel rod will act as a sprag to retain the tappet while the circlip is removed. However where numerous pumps are being overhauled, the use of a fixture as shown in figure 2 may be found convenient.

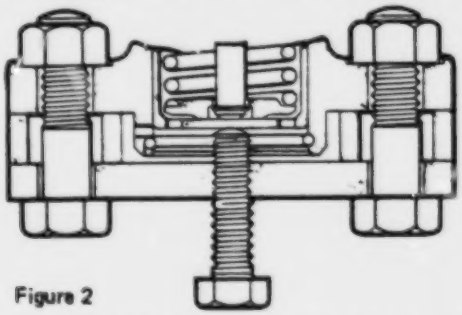


Figure 2

Pull out the lower spring plate (19) with plunger (2A) and place in a clean container taking care to avoid damage, remove plunger spring (18).

Pull out the control sleeve (15) using pliers, this will also lift out the upper spring plate (16) and its retaining circlip (17).

Slide out the control rod (6) without removing the stop cap (11). Do not remove the shim retaining plate (30) and shims (29) until it is known that the spill timing has to be reset, and that facilities for doing so are available.

This will require a fixture for spill timing and a tool for setting the 'pop' rivets which secure the shim retaining plate.

The correct method of removing the shim retaining plate is to drill out the tubular 'pop' rivets with a drill ⅛" or 3.2 mm diameter. Do not attempt to remove the plate by levering it off as this causes damage or distortion.

UPPER END

Remove pump from vice, turn it over so that the delivery connection is uppermost, and grip firmly across the flange. Do not clamp on the spigot as this may cause damage or breakage. Using a good fitting ring or socket wrench 70 mm, 2¾" A/F, or 2" BSF hexagon size, capable of applying around 1000 Nm (750 lbf ft) torque, undo and remove retaining nut (22) with delivery valve holder (27).

Separate these two items and remove 'O' ring (26) and leather washer (25) unless these two seals are known to be in good condition.

Remove 'O' ring (28), delivery valve spring (24), and the delivery valve assembly by lifting the delivery valve thimble part way and tilting.

Remove the locking wire, and unscrew the spill plug and washer (4 & 5) barrel locating screw and washer (3 & 7) and check valve and washer (32 & 7) or blanking plug (33).

Unclamp the housing from the vice, and place it on its side on the bench.

Remove the barrel by pushing or tapping with a soft metal drift, taking care not to touch the bore. If the barrel is hard to move, check that the barrel locating screw has been removed.

When the barrel has been removed, wash it, check that the 2 mm inclined holes are clear using a squirt oil can, assemble it to its mating plunger using clean test oil.

Remove barrel 'O' ring (8) from its groove in the housing. Wash all parts in clean light diesel fuel.

EXAMINATION

'O' ring seals and joint washers. These should be renewed during pump overhaul, particularly if there is any doubt about their suitability for further use. The cost of an unscheduled shutdown of an engine to change or repair a leaking pump will outweigh the cost of replacement seals. However, if circumstances require the re-use of a seal the following points should be noted.

'O' rings must be free from tears, flats or other discontinuity particularly on the outer and inner diameters which form the sealing surfaces. The cross section should be circular, an oval or flattened section will reduce the radial compression which is essential for effective sealing.

Joint Washers must be free from distortion and have unbroken sealing faces without ridges or indentations. Copper washers should be annealed.

ELEMENT ASSEMBLY

The most usual reason for element replacement is wear, or occasionally erosion damage, of the upper end of the plunger in the area swept by the ports.

This reduces pumping efficiency resulting in the need to increase control rod opening, as mentioned in the Introductory notes. Wear is indicated by axial scratching or scoring between the top face and helix. When such scratching has obliterated the original finish of the plunger, or presents discrete scores which can be seen, or felt with a finger nail, the element should be replaced.

With clean fuel, elements may be expected to give 10000 to 20000 hours of service, and a requirement for earlier replacement will indicate the need to improve fuel filtration.

Erosion damage is recognisable as a matt grey shading on the otherwise fine ground or lapped surface of the plunger.

It will be in the area swept by one or other of the ports, not necessarily on the helix side, and the first sign will be a small crescent shaped mark in the position of the upper edge of the port at point of spill.

Gradually the mark will extend, eventually to form an imprint of the entire port on engines running at substantially constant load; when the erosion damage is on the helix side the imprint will reach the helix.

On engines running under constantly varying load, the crescent shaped marks will form a continuous line inclined at the same angle as the helix.

Such erosion is not directly detrimental to element performance until it has reached within 2 mm of the helix or top face of the plunger, at which point the element should be replaced.

Erosion damage progresses at a reasonably uniform rate, thus an estimate of the remaining service life can be made if the hours run to date are known.

If erosion damage is noted only on individual pumps it may be due to a restriction in the injector or high pressure line causing excessive pressure. Check that the nozzle needle lift is correct, that the high pressure pipe ends are not closed, or the edge filter blocked.

Another cause of element deterioration is the presence of water in the fuel, which is indicated by gradual blackening of the mated surfaces of the barrel and plunger by the formation of black iron oxide. This causes breakdown of finish resulting in rapid wear.

Check the top face of the barrel for evidence of leakage, which will show as fine, irregular radial tracking marks.

It is possible to remove these oy lapping provided that they are not too deep, but the sealing face must be maintained parallel to the barrel seating within 0.025 mm across the diameter.

It is unlikely that wear of the plunger lug, or of the foot will be sufficient to require replacement of the element assembly, but these features should be checked for clearance in conjunction with the related working parts, see control sleeve, lower spring plate and tappet.

DELIVERY VALVE ASSEMBLY

Examine both faces for evidence of tracking as described under Element Assembly. If lapping is required, the two faces must be maintained parallel within 0.05 mm measured across the upper face.

The delivery valve assembly can be checked for seat tightness with the pump assembled, by applying air at 3.4–5.5 bar (50–80 lbf/in^2) to the delivery valve holder outlet connection and immersing the pump in test oil or fuel oil.

Replace the assembly if there is leakage, if the unloading collar of the valve thimble is scored, or rounded at the lower edge, or if the mitre seating of either valve thimble or valve seat is ridged or discontinuous.

DELIVERY VALVE HOLDER

Check lower face for evidence of leakage or of incomplete contact with delivery valve seat. If lapping is required, the lower face must be maintained parallel to the clamping shoulder within 0.05 mm.

Check the cone for the high pressure pipe connection, and replace if this is ridged or indented, also if the threads are damaged or distorted.

Note. In lapping the sealing faces of the barrel, delivery valve seat and delivery valve holder to remove imperfections it is important that the combined thickness of these three components from barrel seat shoulder to delivery valve holder clamping shoulder is not less than 86.75 mm.

RETAINING NUT

Check that threads are undamaged, and that it will assemble freely into housing, until the shoulder meets the top face.

LOWER END PARTS

These should all dismantle freely and at the most be coated with a film of carbonised oil on the non-wearing surfaces.

Presence of a cocoa coloured paste indicates poor venting of the tappet chamber — check that all drain holes in pump tappet, and the pump mounting are clear.

Tappet. The outside diameter should be clean, with polished bands extending round the entire periphery for a distance of about 10 mm from each end.

There should be a bright contact mark each side of the end wall, made by the plunger foot, and the engine tappet head.

Any tappet which is cracked in this area, or on which the indentation exceeds 0.05 mm should be replaced as continued running can cause rapid further wear resulting in retarded injection timing, with eventual breakage and other consequential damage.

HOUSING

Check for wear in bore for control rod. With the control rod assembled, at mid travel clearance in horizontal and vertical planes should not exceed 0.25 mm (.01").

CONTROL ROD AND CONTROL SLEEVE

Replace any component with teeth which are visibly worn or damaged. Backlash in the assembled condition should not exceed 0.2 mm (.008").

The slot in the control sleeve should be free from visible wear, or step at top of plunger stroke. Clearance between plunger lug and control sleeve slot should not exceed 0.2 mm (.008").

SPRINGS

Replace any springs showing signs of broken coils, corrosion, pitting, collapse or distortion, the latter being indicated by flats worn on the outside diameter of the coils.

Check for free length, and for squareness of end faces when stood on a flat surface and rotated against a square. Replace if springs do not comply with the following specification.

Spring	No of coils ref only.	MINIMUM LENGTH	SQUARENESS DEVIATION OVER LENGTH
Delivery Valve	20	42.7 mm (1.68")	.6 mm (.024")
Plunger	6½	72.4 mm (2.85")	2.0 mm (.080")

SPRING PLATE LOWER

Check axial clearance for plunger foot by 'trapping' plunger against a flat face. The plunger must be free to rotate, but axial clearance should not exceed 0.25 mm (.010"). [Total clearance, with tappet indented 0.05 mm (.002") not to exceed 0.3 mm (.012").]

Spill plug. Replace this if the erosion crater exceeds 1 mm in depth, or extends to the edge.

Barrel locating screw. Replace if threads or plain end are damaged or chipped.

Check valve (where fitted). Apply an air pressure of 3.4–5.5 bar (50–80 lbf/in^2) to the male thread end (G–¼) and immerse. Replace if any leakage occurs.

REASSEMBLING

Before starting, ensure that all parts are clean, undamaged and ready for use, also that the 'O' ring groove in the barrel locating bore in the housing is free from slivers of rubber which may have been produced when removing the old 'O' ring.

Soak leather washer (25) in clean test oil for at least 10 minutes to ensure that it is flexible.

Various checks are required during assembly or testing, depending on the work done or new parts fitted. Partial dismantling of the pump will be necessary.

These checks are:—

1 Verification that there is even 360° contact marking between the sealing faces of the delivery valve holder and delivery valve seat. This is particularly necessary if element assembly, delivery valve assembly, delivery valve holder, retaining nut, or housing have been replaced, or lapped on the sealing faces.

2 Air test of low pressure seals.

3 Measurement, and if necessary, adjustment of spill timing. This is required if element assembly, tappet or housing have been replaced, or if there is indentation of the tappet faces, and must be carried out with the delivery valve thimble removed.

For checks 2 & 3 refer to service test specification 'FCVAB general', and the subsection for the particular pump.

The following assembly procedure assumes that if spill timing is required, or supply of test oil at a pressure of 14 bar (200 lbf/in²) is available to lift the delivery valve.

If the gravity head method is to be used for spill timing, the pump should be assembled without delivery valve thimble and spring. The check for contact marking can be made after spill timing, when the delivery valve thimble and spring are being fitted.

PROCEDURE

UPPER END

Fit oiled leather washer (25) to bore in retaining nut (22) with the smooth side pushed flat against the shoulder, followed by greased 'O' ring (26) and delivery valve holder (27) the latter being pushed home.

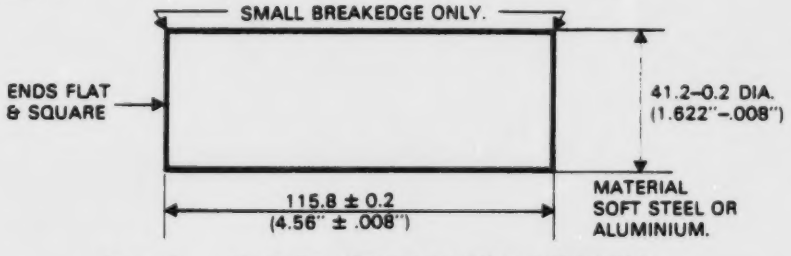


Figure 3 PLUG TO ASSIST 'O' RING ASSEMBLY

Assembly of 'O' ring (8) to housing will be assisted by using a soft metal plug as shown in Fig. 3

Stand the housing (1) upright with the soft metal plug entered into the barrel locating bore until the top face is level with the lower edge of the 'O' ring groove.

Push a greased 'O' ring (8) from the top of the housing onto the face of the plug, and using two clean rods free from sharp edges push the 'O' ring into the groove until it is evenly bedded.

(Hardwood or hard plastic or aluminium knitting needles are suitable. Pencils are not recommended as loose paint or wood slivers may lodge under sealing faces.) Remove the plug.

Place the housing horizontally on the work surface, with the tapping for the barrel locating screw facing upwards. (This is the G⅛ through tapping next to the spill plug.)

Enter the barrel into the housing with the locating slot facing upwards, and push it onto its seating.

Check that the slot is central in the tapping, using a smooth steel rod not exceeding 6.35 mm (¼") diameter if necessary to rotate the barrel.

Fit a new washer (7) to the barrel locating screw (3) and screw finger tight until the plain end has entered the barrel locating slot.

Check that it has entered by pushing the barrel away from its seating, it should move only 1–1.5 mm before being stopped by the screw.

Tighten the screw only when it is evident that it has located the barrel, and push the barrel back onto its seat.

UPPER END

Grip housing firmly in a vice, across the flange, top end upwards. Place the delivery valve assembly with spring in position on the barrel, central by eye.

Place greased 'O' ring (28) on spigot of retaining nut.

Smear threads of retaining nut (22) with Molybdenum Disulphide grease and screw the nut, with delivery valve holder, into the housing.

Tighten to 810/880 Nm (600/650 lbf ft) using a steady pull. A torque wrench with a handle of 1.5 m (60") or double handle is necessary.

After tightening, slacken and remove the retaining nut and check that there is even width contact marking over 360° between the mating faces of the delivery valve holder and the delivery valve seat.

If satisfactory, reassemble and tighten again to 810/880 Nm (600/650 lbf ft). If not satisfactory, correct flatness or parallelism of delivery valve holder, delivery valve seat, or element barrel as necessary.

Place washer (5) on spill plug (4) screw into housing and tighten. (5/16" AF hexagon Socket key.) Wire lock spill plug & barrel locating screw. Fit blanks to fuel outlet connection, fuel inlet tapping and connector for airline to fuel return tapping (G¼ thread) in preparation for air test.

Release housing from vice, turn upside down, and grip in vice by the flats on the retaining nut.

Push control rod into housing, check that it slides freely over its travel, and move the middle tooth which is marked with a gash to a central position.

Assemble the control sleeve (15) so that the tooth space marked with a punch dot engages with the marked control rod tooth.

Check that the control rod slides freely over the travel which is limited by the curved tooth runout abutting the control sleeve outer diameter — approximately 36 mm.

Assemble upper spring plate (16), and circlip (17) pushing the latter until it traps the spring plate.

Put plunger spring (18) in position, press it against the spring plate and check that control rod is still free.

Fit lower spring plate over plunger foot, assemble plunger carefully to barrel, and align the plunger lug with the slot in the control sleeve. Check alignment by pressing plunger foot and moving the control rod until the lug engages and the plunger is rotated by control rod movement.

Release plunger, but do not rotate it or move the control rod.

Put the tappet (20) in position and depress it until the end face is below the circlip groove in the housing.

If the tappet is stopped before reaching the circlip groove, the plunger lug has not entered the slot. Do not apply force, but feel it into engagement by moving the control rod a small amount in each direction while alternately pressing and releasing the tappet.

Sprag the tappet by pushing a 3–4 mm steel rod through the hole in the spigot. Fit circlip (21) making sure that it has bedded in the groove. Withdraw the steel rod. Unclamp pump from vice.

The general procedure for Static Test, which sets the timing, and for Dynamic Test which checks and adjusts the output is shown in Service Test Specification FCVAB.

For test details of specific pump types, refer to the subsection for the particular pump.

This subsection is identified by a numerical code which is derived from the pump typecode.

FCVAB**180B0772**

The correct subsection is 0772/180.
The first four digits are the symbol number suffix to the full typecode.

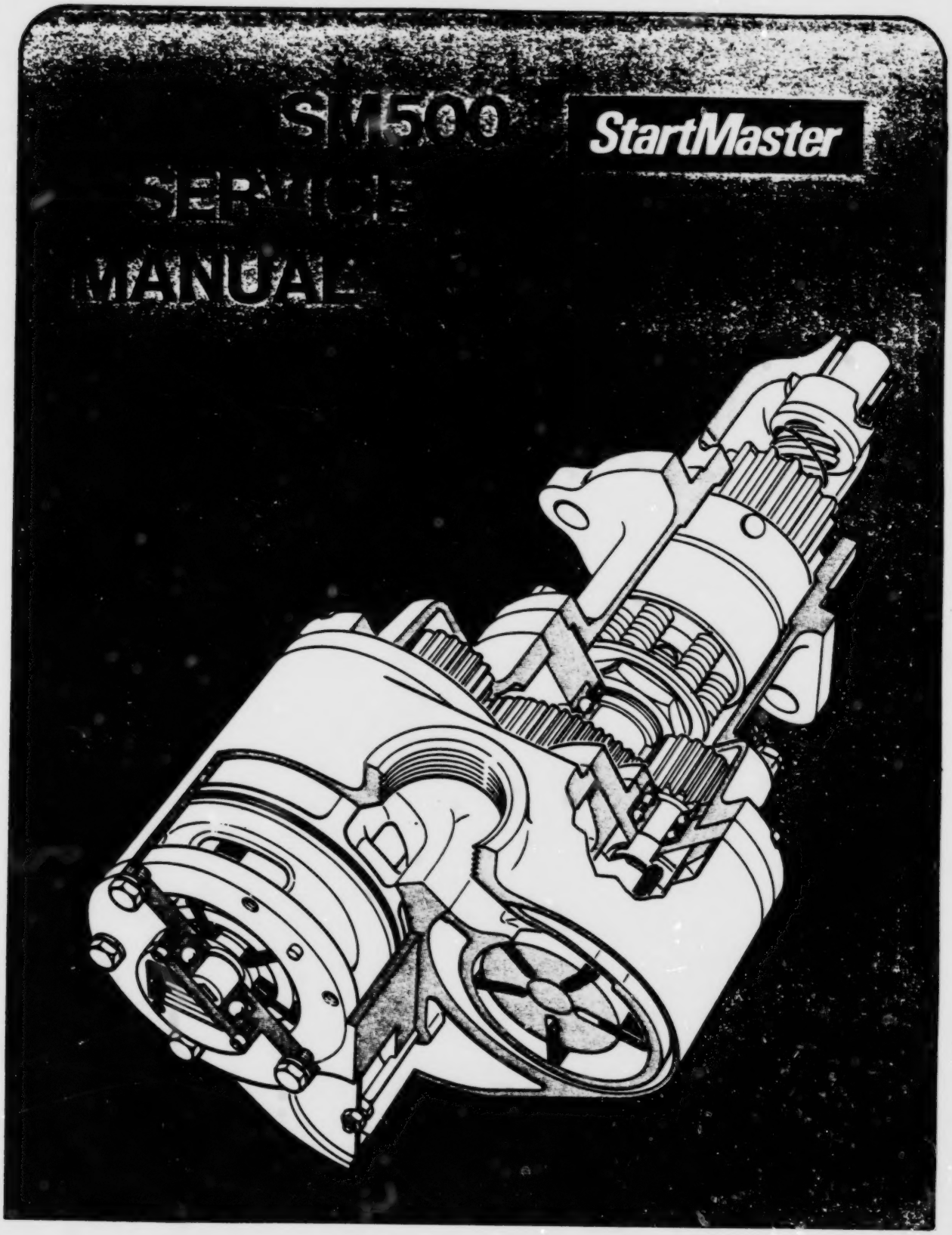
The last three digits denote the element plunger diameter in 1/10ths millimetres thus 180 denotes a 18 mm diameter plunger.

PARTS LIST – PUMP FCVAB180B0772

ITEM	PART NUMBER	QTY.
1 - Pump Housing	36/168	1
2 - Element Assembly	36/171C	1
3 - Screw, Barrel Locating	36/27	1
4 - Spill Plug	21/201	1
5 - Washer, Spill Plug	113/62	1
6 - Control Rod	36/173	1
7 - Washer, Locating Screw	NW5/22	2
8 - Seal, O-Ring	372/18	1
9 - Pointer, Control Rod	36/177	1
Screw, Pointer	365/C	2
Shims, Pointer	6/351 A-H	A/R
10 - Lockwire	18 SWG	A/R
11 - Stop Cap, Control Rod	36/174	1
Screw, Stop Cap	373/3	1
13 - Delivery Valve & Seat Assembly	36/54 J	1
15 - Control Sleeve	36/30	1
16 - Spring Plate, Upper	7022/232	1
17 - Circlip, Upper	25/25	1
18 - Spring, Plunger	36/31	1
19 - Spring Plate, Lower	6/107	1
20 - Tappet	6/289	1
21 - Circlip, Lower	6/105	1
22 - Retaining Nut	36/56	1
24 - Spring, Delivery Valve	36/34	1
25 - Washer, O-Ring	106/116	1
26 - Seal, O-Ring	372/15	1
27 - Delivery Valve Holder	36/39	1
28 - Seal, O-Ring	372/36	1
29 - Shim, Pump Housing	36/170	A/R
30 - Shim Plate, Pump Housing	36/169	1
Tucker Rivets	369/1	4
33 - Blanking Plug	119/5081	1

SM500 StartMaster

SERVICE MANUAL



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SECTION I · INTRODUCTION · STARTMASTER SERIES SM500 AIR STARTER

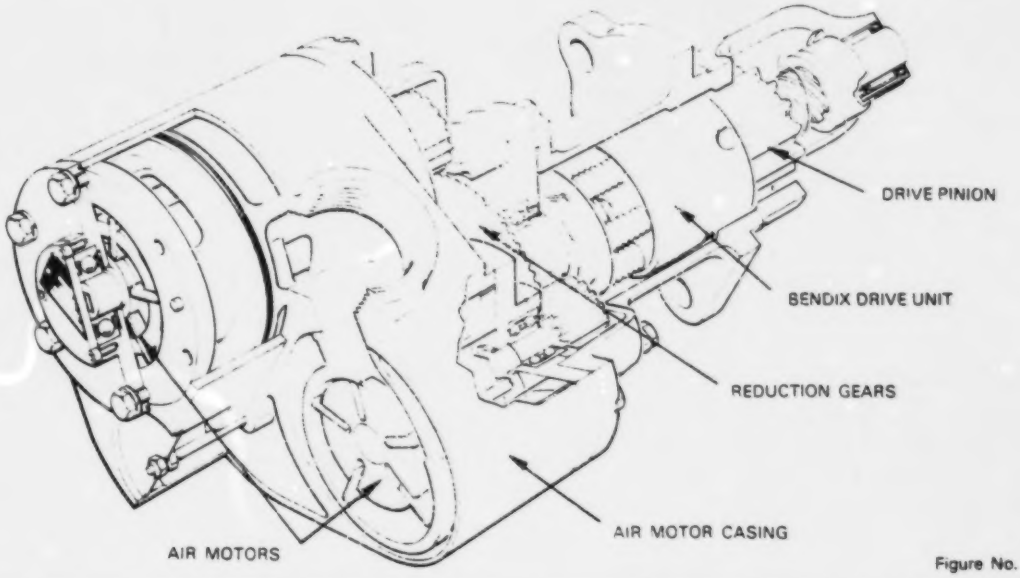


Figure No. 1.1

The StartMaster Series SM500 air starters are reduction drive, inertia engagement models. The Model SM500 is available with different pinions, right-hand or left-hand rotation, and is equipped with either an SAE No. 3 (See Figure No. 1.1) or a special three-bolt mounting flange (See Figure No. 1.2).

THE AIR MOTOR

The air motor incorporated in the SM500 series differs from those used in other StartMaster starters. The sleeve assemblies are mounted on the gear case and the air motor casing floats on the o-ring seals on each of the two sleeves.

A complete discussion of the construction, operation and overhaul of the air motor is contained in Section III.

ABOUT THE MANUAL

This Service manual contains fold-out pages in the last section. These pages may be folded out while using the text and photographs in each section to aid in the identifying components during rebuilding. Refer to the individual model specification sheet when performing repairs on any StartMaster air starter.

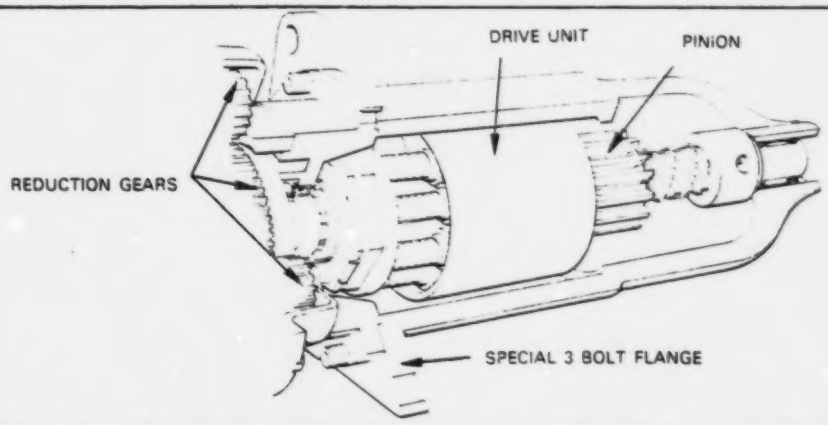


Figure No. 1.2

StartMaster

SECTION II · DISASSEMBLY OF DRIVE GROUP

The Series SM500 drive group (See Figure No. 1.1 and No. 1.2) consists of a drive shaft assembly, a reduction gear set, a gear case and a drive housing.

The drive shaft assembly consists of a Bendix drive unit and drive shaft gear (of the reduction gear set) mounted on the drive shaft. The Bendix unit is mounted to one end of the drive shaft and the drive shaft gear is keyed to the other end.

The drive shaft assembly is supported by two roller bearings (one located in the nose of the drive housing and the other located in the gear case) and a ball bearing mounted in the gear case cover.

The reduction gear set consists of the rotor pinions and drive shaft gear. The rotor pinions are splined to the rotor shafts and retained by the pinion retaining rings. The drive shaft gear is keyed to the drive shaft.

II-1. SAE #3 TYPE FLANGE

Disassemble the drive group in accordance with the parts indexing shown in Fold-Out No. 1 and the following instructions:

1. Install a 1¼" to 2" pipe bushing on StartMaster Tool No. 20099. Insert the tool into the inlet air connection of the SM500 air motor and mount the starter in the vise as shown in Figure No. 2.1.
2. Scribe a reference mark on the drive housing, gear case cover, and gear case, as shown in Figure No. 2.2
3. Loosen and remove the eight drive housing nuts (5) lockwashers (6).
4. Pull the drive housing (4) from the gear case.

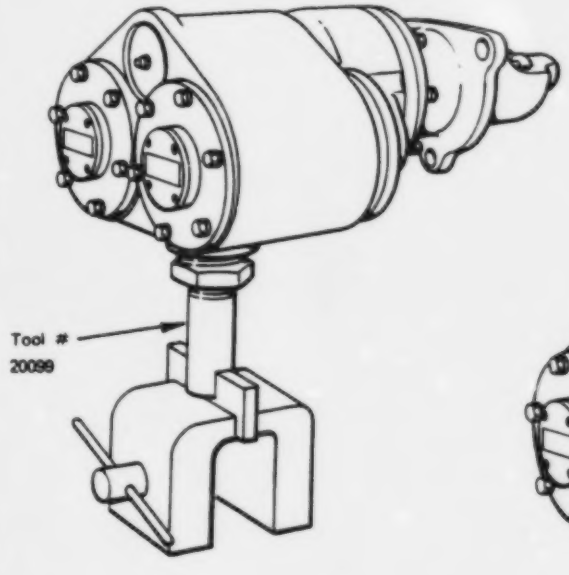


Figure No. 2.1 · Mounting the Starter

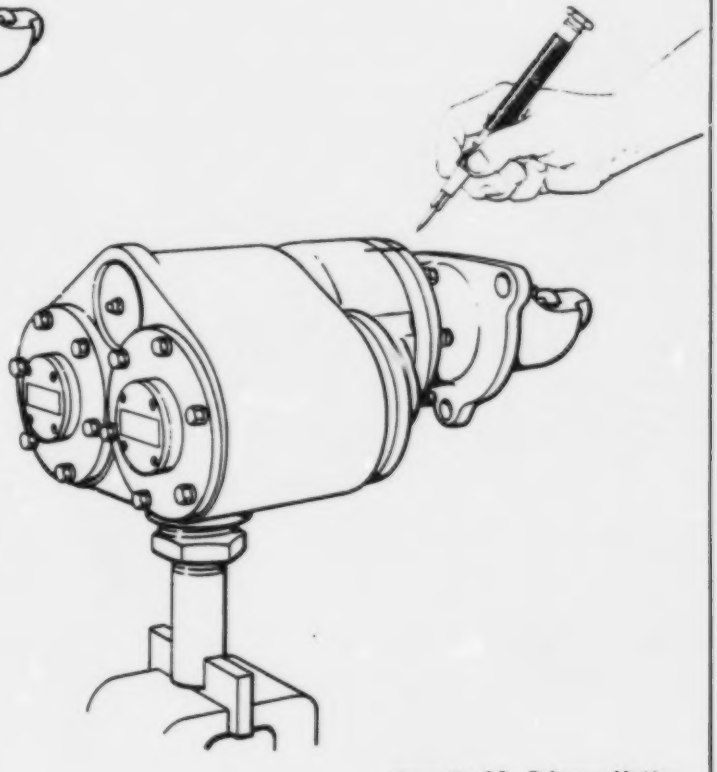


Figure No. 2.2 · Reference Marking

5. Locate the drive unit retaining screw in the vicinity of the clutch pack springs. Pry the retaining ring to the side and remove the drive retaining screw. See Figure No. 2.3.
6. Grasp the drive unit (7) and pull it from the drive shaft.

NOTE: A spring [8] is incorporated within the Bendix drive unit. This spring bears on the end of the drive shaft and on the end of the drive shaft hole in the drive unit. After the drive unit is removed, the spring is free. Tag wire the spring to the drive unit to insure that it is not lost during cleaning and handling.

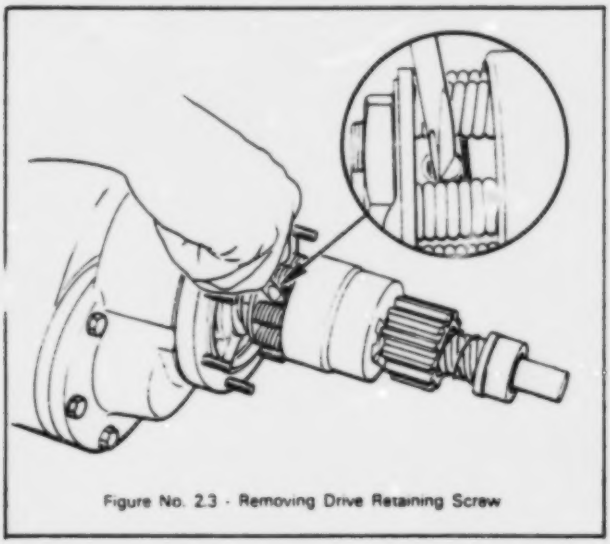


Figure No. 2.3 - Removing Drive Retaining Screw

7. Using a suitable tool, as shown in Figure No. 2.4, press the two drive housing seals (1 and 3) and drive bearing (2) from the drive housing (4).
8. Remove the two drive shaft keys (10).
9. Grasp the drive shaft (9) while tapping the gear case cover (12) with a plastic mallet and remove the drive shaft gear assembly. See Figure No. 2.5.
10. Remove and discard the gear case seal ring (13).
11. Remove the drive shaft thrust bearing (17).
12. Support the gear case cover, as shown in Figure 2.6. Press the drive shaft (9) and gear (16) and bearing (15) from the cover.
13. Press the drive shaft (9) from the drive shaft gear (16), as shown in Figure 2.7.
14. Remove the gear key (11) from the drive shaft (9).
15. Press the drive shaft bearing (15) from the drive shaft (9), as shown in Figure 2.8.
16. Press the drive shaft seal (14) from the gear case cover (12), as shown in Figure No. 2.9.

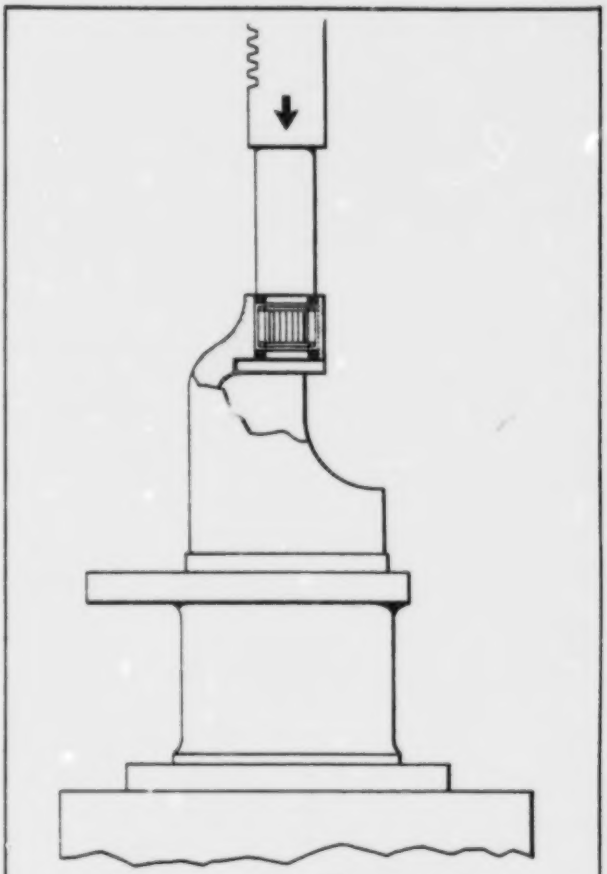


Figure No. 2.4 - Removing Drive Bearing and Seals

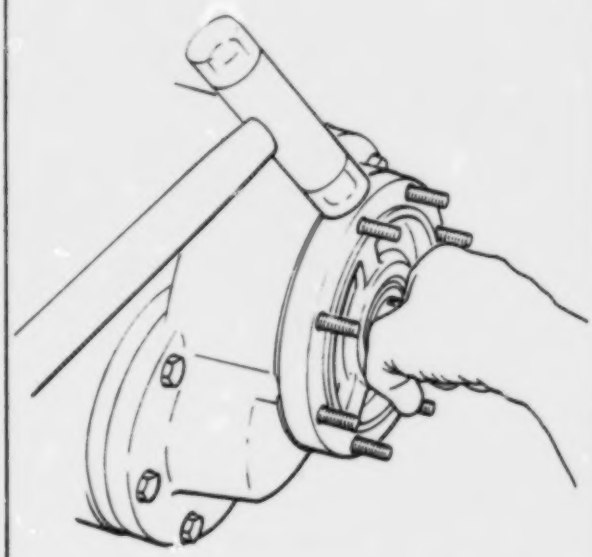


Figure No. 2.5 - Removing Drive Shaft Gear Assembly

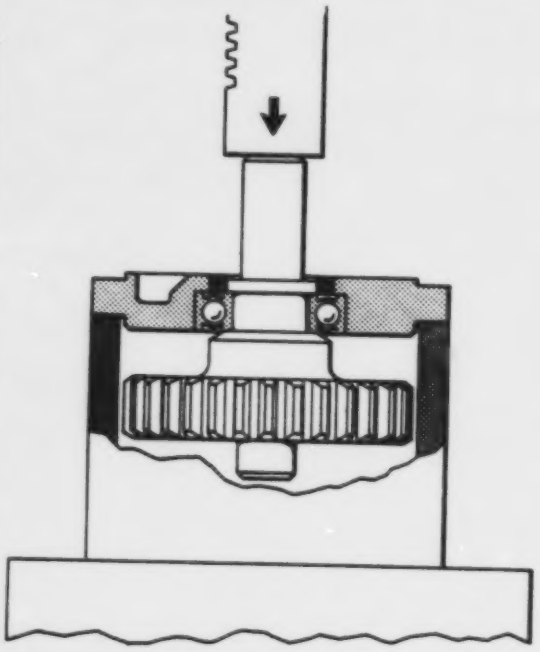


Figure No. 2.6 - Pressing Drive Shaft, Gear, and Bearing from Cover

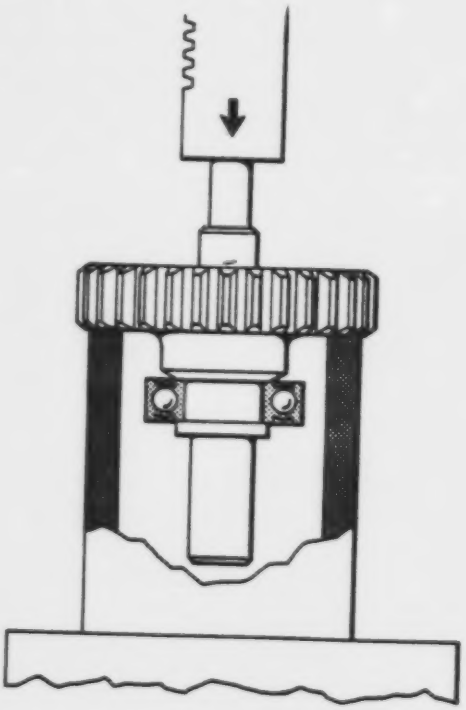


Figure No. 2.7 - Pressing Drive Shaft from Gear

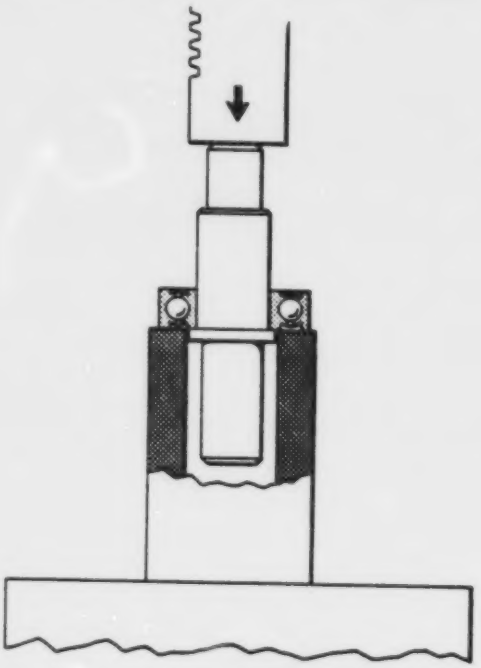


Figure No. 2.8 - Pressing Drive Shaft from Bearing

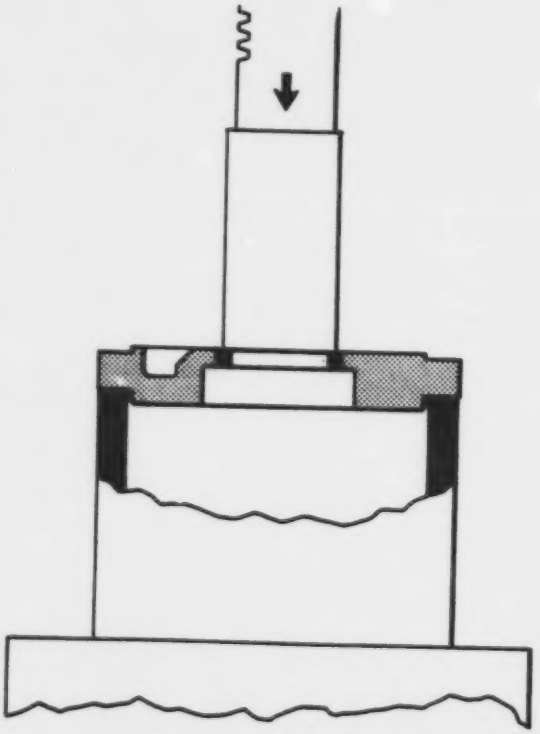


Figure No. 2.9 - Pressing Seal from Cover

II-2. SPECIAL THREE BOLT TYPE FLANGE

Disassemble the drive group in accordance with the parts indexing shown in Fold-Out No. 2 and the following instructions:

1. Install a 1¼" to 2" pipe bushing on StartMaster Tool No. 20099. Insert the tool into the inlet air connection of the SM500 air motor and mount the starter in the vise as shown in Figure No. 2.1.
2. Scribe a reference mark on the drive housing, gear case cover, and gear case, as shown in Figure No. 2.2
3. Loosen and remove six drive housing socket head cap screws (5) and their lockwashers (6).
4. Lift the drive housing (4) from the gear case.

NOTE: The Bendix drive unit in this housing is not secured to the output drive shaft. It may be necessary to hold the drive unit in place while removing the drive housing.

5. Withdraw the Bendix drive unit (7) and thrust washer (8) from the output drive shaft.
6. Remove the drive unit spacer (10) from the output drive shaft.
7. Remove the eight socket head cap screws (18) and lockwashers (19) holding the gear case cover to the gear case.
8. Using a suitable tool, similar to that as shown in Figure No. 2.4, press the two drive housing seals (1 and 3) and the drive bearing (2) from the drive housing(4).
9. Refer to Section II-1, Step 9, for further disassembly instructions.

II-A. DRIVE GROUP -

CLEANING, INSPECTION AND PARTS REPLACEMENT

CLEANING

WARNING

Perform all cleaning procedures in a well ventilated area away from open flame.

1. Clean all parts removed during disassembly using commercially approved solvents.
2. Clean the Bendix drive unit by wiping thoroughly with a clean cloth.

CAUTION

Do not immerse sealed assemblies such as the drive unit in cleaning solvent. Doing so will wash away internal lubrication.

3. Carefully remove all dirt, grease, gasket residue and burrs from mating gasket surfaces.

INSPECTION AND PARTS REPLACEMENT

1. Replace all gaskets and seals removed during disassembly.
2. Inspect all parts removed during disassembly for evidence of excessive or abnormal wear or other damage. Particular attention should be given to the following parts:

Drive Housing:
Visually inspect the drive housing for cracks and breakage and replace if necessary.

Gear Case Cover:
Visually inspect the gear case cover for cracks and breakage and replace if necessary.

Bearings:
Check the drive unit bearing to insure that the bearing rollers move freely and have not been flattened or otherwise damaged. Check the drive shaft ball bearing for freedom of rotation without excessive play between the races. Replace questionable bearings.

Bendix Drive Unit:
Inspect the drive unit for worn (loose), missing, or damaged parts. Check the drive pinion for damage or excessive wear. Defective drive assemblies cannot be rebuilt and must be replaced as a unit.

Drive Shaft Gear:
Inspect the drive shaft gear for cracked or broken teeth or excessive wear. Check for unusual contact patterns indicating run out between gears, misalignment, or improper engagement. Replace a damaged or questionable drive shaft gear.

OVERHAUL

Replace the following drive group parts during the complete overhaul of the Series SM500: Bendix Drive Unit, Drive Bearing, All Gaskets and Seals, Drive Shaft Ball Bearing, and Thrust Bearing.

SECTION III - DISASSEMBLY OF AIR MOTOR GROUP

The SM500 air motor consists of two sleeve assemblies and two rotors. The sleeve assemblies are mounted to the gear case and endplates, and are surrounded by the air motor casing. Rotation of the air motor is determined by the air flow direction through the sleeve assemblies. Reversing the sleeve assemblies end for end will change direction of air motor rotation. Disassemble the SM500 air motor in accordance with the parts indexing shown in Fold-Out No. 3 and the following instructions:

1. Remove as much grease as possible from the gear case housing (35) to reveal the four gear case screws that are located inside the gear case cover.
2. Remove the screws (36) and washers (37) from the gear case assembly.
3. Remove the gear case assembly from the air motor casing and discard the two gear case gaskets (38).
4. Press the drive shaft roller bearing (34) from the gear case (35), as shown in Figure No. 3.1.
5. Using Tool No. 20044, remove the pinion retaining rings (39) from the rotor shafts. See Figure No. 3.2.
6. Remove the rotor pinions (40) from their shafts.
7. Remove the twelve endplate screws (5) and washers (4) from the rear of the dual air motor assembly.

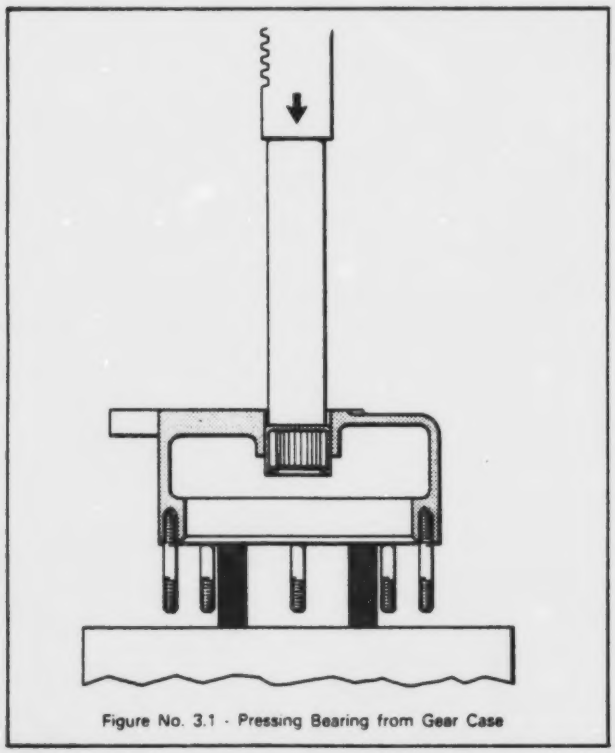


Figure No. 3.1 - Pressing Bearing from Gear Case

NOTE: Some models of the SM500 designed for use with compressed air and all models of the SM500 utilizing natural gas for operation, use an exhaust adaptor. If so equipped, removal of the adaptor is necessary prior to continuing motor disassembly. Proceed as follows: Remove exhaust adaptor mounting screws [22] and remove the adaptor [21] from the rear of the air motor casing. Remove and discard the motor exhaust seal [19] and the four exhaust seal washers [20].

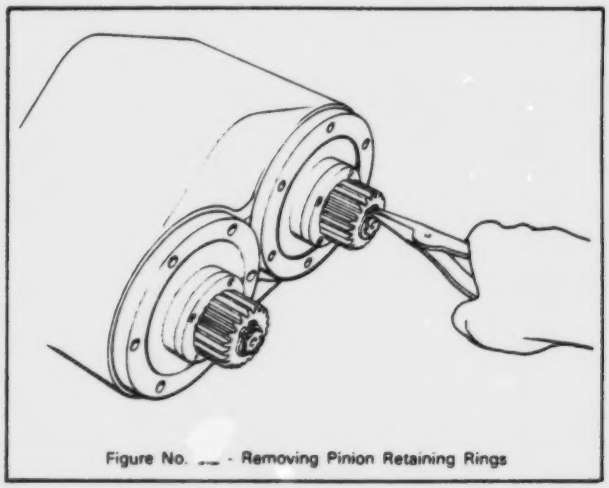


Figure No. ... - Removing Pinion Retaining Rings

8. Grasp the rear endplates (3), and while tapping gently with a hammer, pull the endplates from the rear of the air motor. Discard the endplate seals (2).

NOTE: The rotor shaft bearings [6] are slipfitted to the air motor drive shaft and should come off easily.

9. Tap the front endplate gently with a hammer to loosen the plate from the air motor casing. See Figure No. 3.3
10. Grasp the air motor drive shaft and slide each rotor assembly from the air motor casing, as shown in Figure No. 3.4. Remove the rotor blades (30) and discard the endplate seals (28).
11. Heat the rotor and endplate assemblies to approximately 350 degrees F (177 degrees C) for ½ hour to soften the Loctite on the rotor shafts. Support the rotor and endplate as shown in Figure No. 3.5 and press the rotor assemblies from the endplates.
12. Remove the four bearing retaining screws (23) and washers (24) from each of the endplate bearing retainers (25) and remove retainers.
13. Press the rotor shaft bearings (26) from each of the two front endplates (27), as shown in Figure No. 3.6.

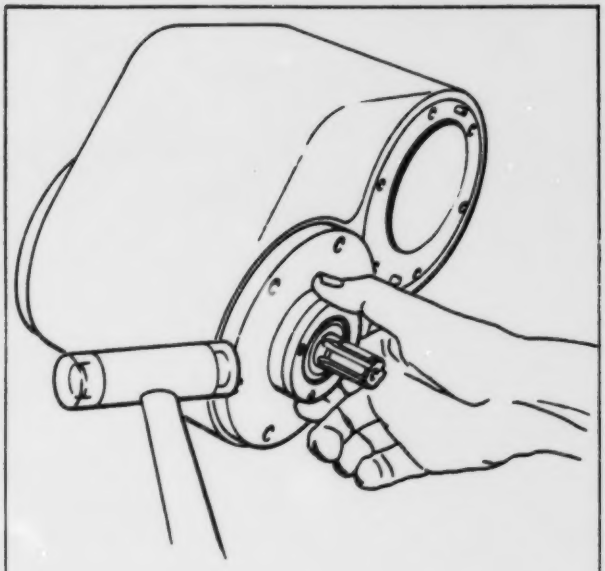


Figure No. 3.3 - Tapping Endplate to Loosen

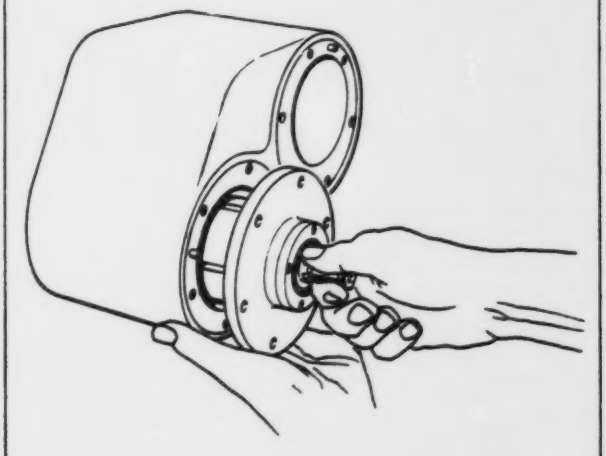


Figure No. 3.4 - Removing Rotor Assembly

14. Remove four bearing retainer screws (10) and washers (9) from each rear bearing cover (8) and discard the bearing cover gaskets (7).
15. Press the rear rotor shaft bearing (6) from each of the rear endplates (3), as shown in Figure No. 3.7.
16. Support the air motor casing (1) in an arbor press, as shown in Figure No. 3.8 and press each air motor sleeve (32) from the air motor casing.

NOTE: The air motor sleeves must be pressed out from the front end of the air motor casing. Discard the two air motor sleeve seals on each sleeve after removal.

17. Insert a 7/16" end wrench into the front exhaust port of the air motor casing to hold the exhaust valve nut (11) while turning the rear exhaust valve nut (18) with a 7/16" socket and ratchet. See Figure No. 3.9.
18. Remove the exhaust valve plate (17), shaft (15), spring (13) and spring guides (12 and 14).

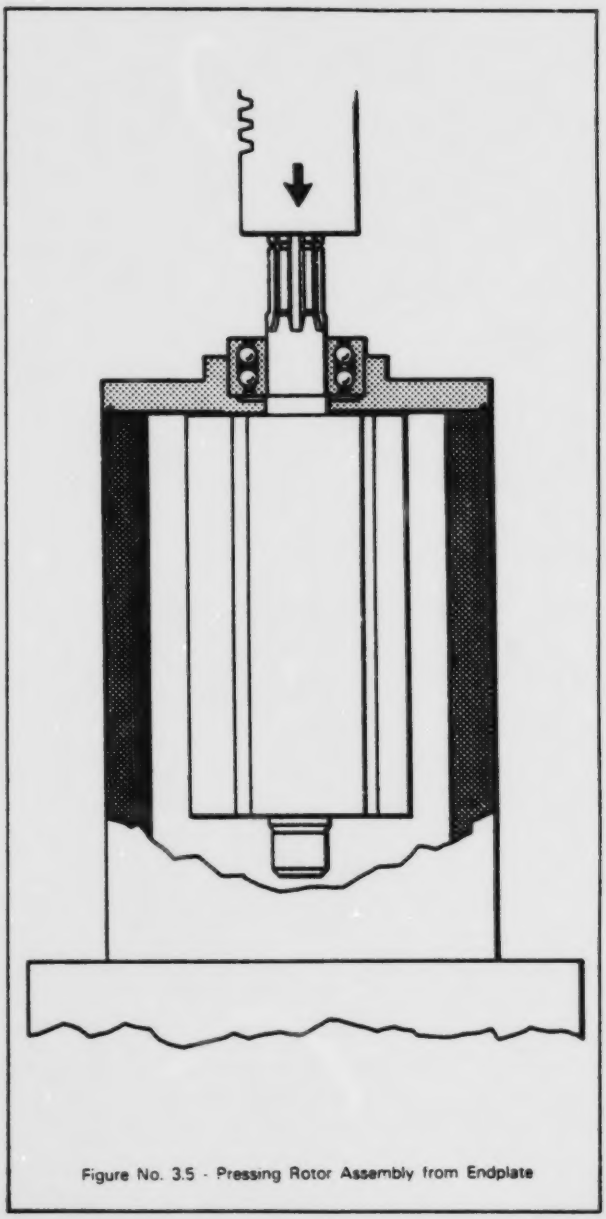


Figure No. 3.5 - Pressing Rotor Assembly from Endplate

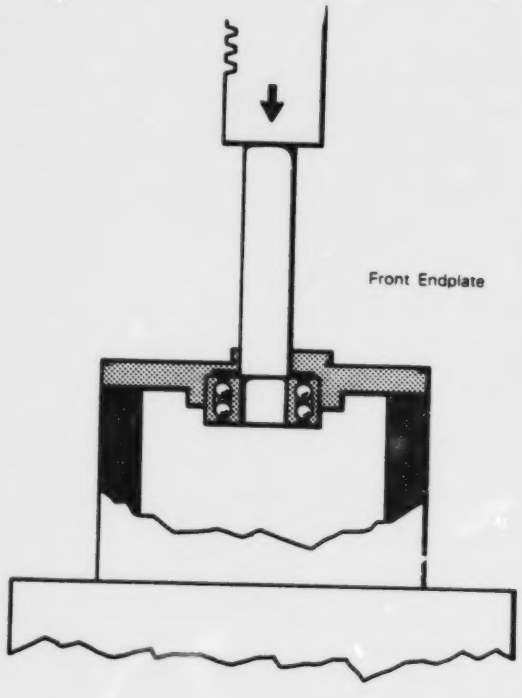
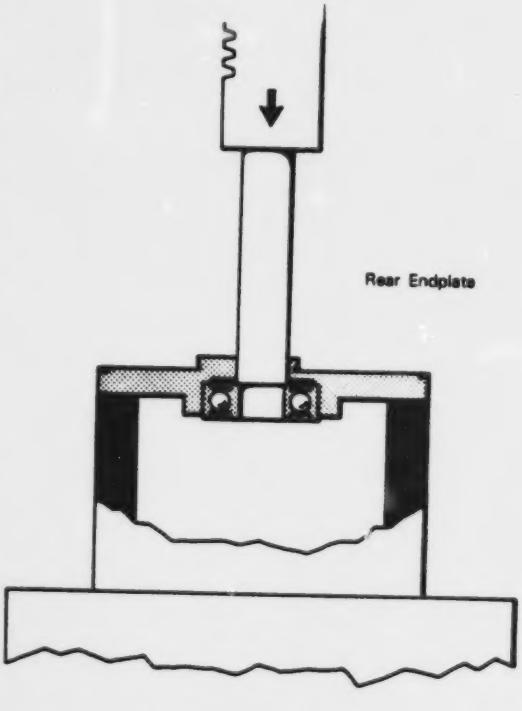


Figure No's. 3.6 and 3.7 - Pressing Rotor Shaft Bearings from Endplates



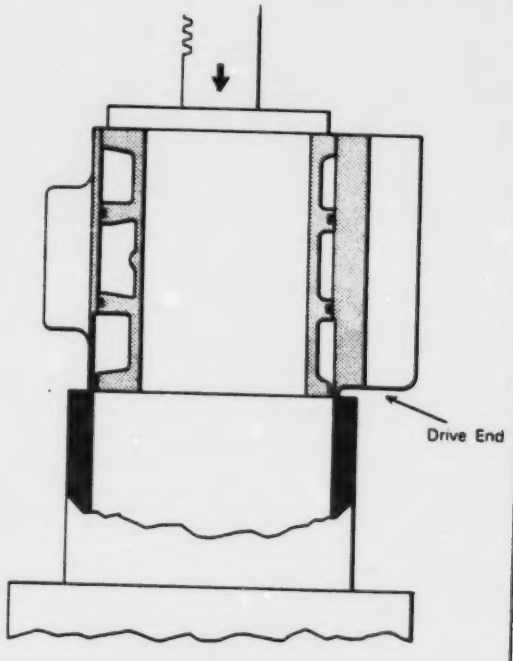


Figure No. 3.8 - Pressing Air Motor Sleeve from Casing

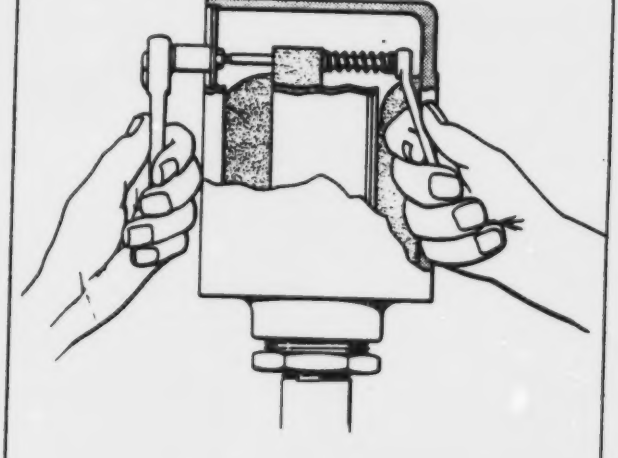


Figure No. 3.9 - Removing Exhaust Valve

III-A. AIR MOTOR GROUP - CLEANING, INSPECTION AND PARTS REPLACEMENT

CLEANING

WARNING

Perform all cleaning procedures in a well ventilated area and away from open flame.

1. Clean all parts removed during disassembly using commercially approved solvents. Do not spin open ball bearings with compressed air.
2. Clean all sealed ball bearings by wiping thoroughly with a clean cloth.

CAUTION

Do not immerse sealed assemblies such as shielded ball bearings in cleaning solvents. Doing so will wash away internal lubrication.

3. Carefully remove all dirt, grease, gasket residue and burrs from mating gasket surfaces.

INSPECTION AND PARTS REPLACEMENT

1. Replace all gaskets and seals removed during disassembly.
2. Inspect all parts removed during disassembly for evidence of excessive or abnormal wear or other damage. Particular attention should be given to the following parts:

Motor Housing:
Visually inspect the exterior of the housing and the liner sleeve bore for cracks. If the liner requires remachining or honing, do not exceed an inside diameter of 3.543" (89.99mm). Visually inspect all ports for chipping and all bolt holes for stripped or broken threads. A housing with damaged inlet port, outlet port or bolt hole threads or cracks must be replaced.

Rotor Assembly:
Visually inspect the rotor body for nicks, scored areas or cracks at the bottom of the blade slots. Check the rotor shaft for straightness and insure that it is locked firmly within the rotor body. Check the shaft ends for scoring or wear at the bearing areas or damage to the splines. Damage to any part of the rotor requires replacement of the complete rotor assembly.

Blades:
Inspect the blades for cracks, delamination, chipping or warpage. Particular attention should be given to the sealing surface of the blades. If the sealing edge chamfer is no longer visible, the blade should be considered worn-out. Damaged or worn blades should be replaced in sets of five only.

Endplate Assemblies:
Inspect the endplate assemblies for scored surfaces and other damage. Ball bearings, which are removed from endplates, must be replaced. If bearings are not removed, they should be checked for freedom and smoothness of rotation.

Gear Case:
Visually inspect the gear case and cover for cracks and breakage and replace if necessary.

Rotor Pinions:
Inspect the rotor pinions for cracked or broken teeth or excessive wear. Check for unusual contact patterns indicating run out between gears, misalignment, or improper engagement. Replace any damaged or questionable gears.

OVERHAUL

The following air motor group parts must be replaced during complete overhaul of the Series SM500: Front Endplate Bearings, Rear Endplate Bearings, All Rotor Blades, All Gaskets and Seals, Drive Shaft Roller Bearing.

SECTION IV - REASSEMBLY OF AIR MOTOR GROUP

Reassembly of the air motor can be accomplished by following the reverse order of disassembly and referring to Fold-Out No. 3. If the air motor is equipped with an exhaust adapter, proceed directly to Step No. 5.

1. If the starter undergoing repair utilizes the exhaust valve assembly, begin by assembling the exhaust valve jam nut (16) to the exhaust valve shaft (15) using the proper thread locking compound and assemble to the dimensions shown in Figure No. 4.1.

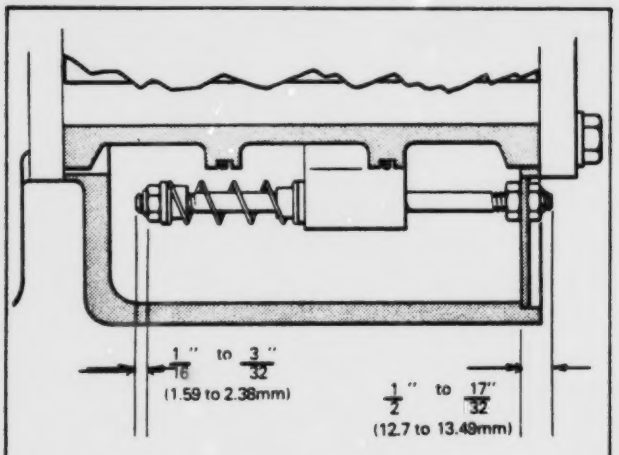


Figure No. 4.1 - Exhaust Valve Assembly

NOTE: Curing of the thread locking compound will require considerable time. This step may be completed prior to total reassembly of the starter.

2. Install the exhaust valve plate (17) and exhaust valve nut (18) and tighten securely.
3. Install the shaft assembly through the valve shaft bore in the air motor housing. See Figure No. 4.1.
4. Assemble the exhaust valve spring (13), guides (12 and 14), and nut (11) in Figure No. 4.1.

NOTE: The exhaust valve spring nut should be tightened to the shaft until 1/16" to 3/32" of the threaded end of the exhaust valve shaft is protruding beyond the nut. Access to the exhaust port area may be obtained through the exhaust cutout in the front of the air motor casing.

5. Press the double row bearings (26) into the front motor endplates (27), as shown in Figure No. 4.2.

NOTE: It is imperative that when pressing the drive shaft bearing into the cover and drive shaft into its bearing, the assembly forces are not transmitted through the balls in the bearing or damage will result.

6. Heat each endplate and bearing assembly to approximately 350 degrees F (177 degrees C) for ½ hour to expand the inner race of the endplate bearing. Support each endplate assembly as shown in Figure No. 4.3 and place .002" (.05mm) feeler gauges on the endplates. Apply a small amount of #35 Loctite retaining compound to the rotor shaft bearing diameter. Press the rotor assembly into the upper endplate bearing until it bottoms against feelers and hold in position for approximately 30 seconds while the bearing cools to grip the rotor shaft.

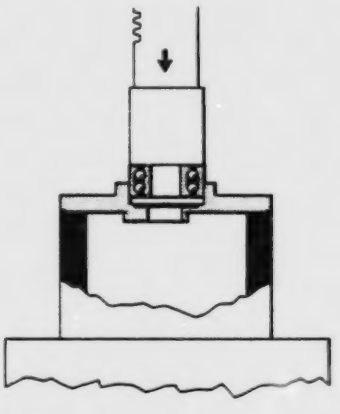


Figure No. 4.2 - Pressing Bearing into Front Endplate

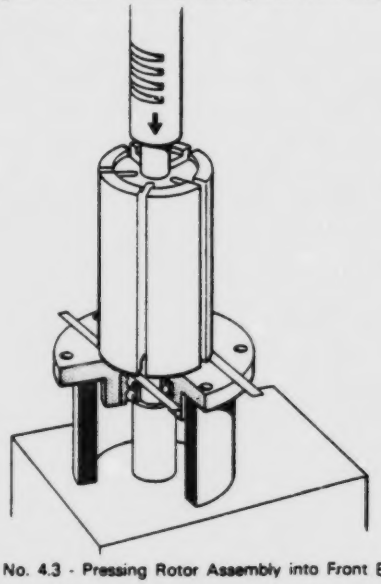


Figure No. 4.3 - Pressing Rotor Assembly into Front Endplate

NOTE: After the endplate and rotor assemblies have cooled, check the rotor end clearance. Rotor clearance should be between .003" and .006" [.08 to .15mm].

7. Install the bearing retainer (25), retainer lockwashers (24) and screws (23), and torque to 25 - 30 in.-lbs. (2.8 to 3.4 Nm.)
8. Install new air motor sleeve seals (31 and 33) on the air motor sleeves (32).
9. Coat the inside diameter of the air motor casing (1) in the sleeve seal area and the newly installed seals with a generous coating of silicone grease.
10. Align the direction arrows of the air motor sleeve assemblies (32) for the desired air motor rotation (opposite starter pinion rotation). Orient the air motor sleeves to align the air inlet passages with those in the motor housing. Press the air motor sleeve into the air motor casing, as shown in Figure No. 4.4.

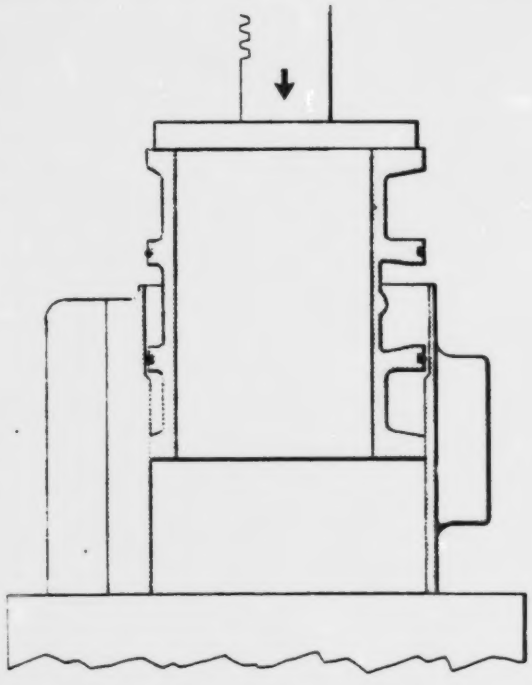


Figure No. 4.4 - Pressing Sleeve into Air Motor Casing

NOTE: It is imperative that the sleeve assemblies be pressed into the front [drive end] of the air motor casing. Entrance bevels are incorporated in the drive end of the casing in order to properly compress the sleeve seals during installation. Tuck the "O" ring seals into their seal grooves as they slide past the air inlet holes to avoid shearing them.

11. Assemble new endplate seals (28) around the rotor assembly onto the endplate (27).
12. Mount the air motor housing on StartMaster Tool No. 20099 using a 1¼" to 2" pipe bushing.
13. Insert the endplate and rotor assemblies into the air motor sleeves as shown in Figure No. 4.5.
14. Install the air motor pinions (40) and secure in place with the pinion retaining rings (39), as shown in Figure No. 4.6.
15. Press the drive shaft roller bearing (34) into the gear case (35), as shown in Figure No. 4.7.
16. Assemble new gear case cover gaskets (38) to the air motor sleeves.

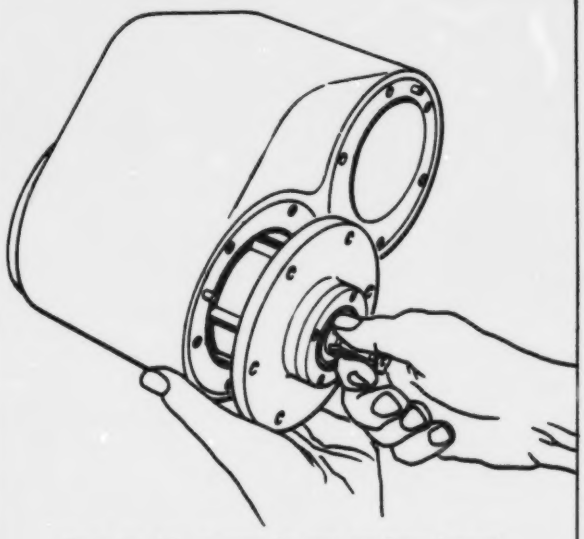


Figure No. 4.5 - Inserting Endplate and Rotor Assembly

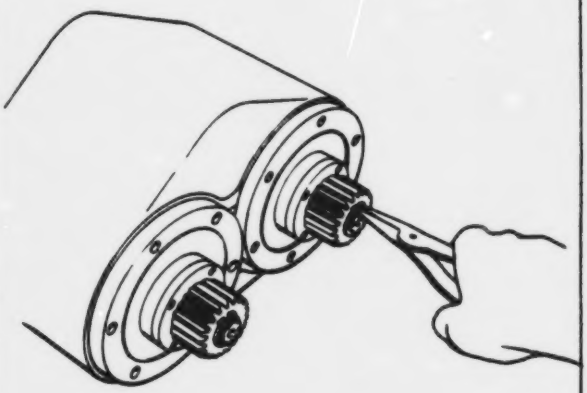


Figure No. 4.6 - Securing Rotor Pinions with Retaining Rings

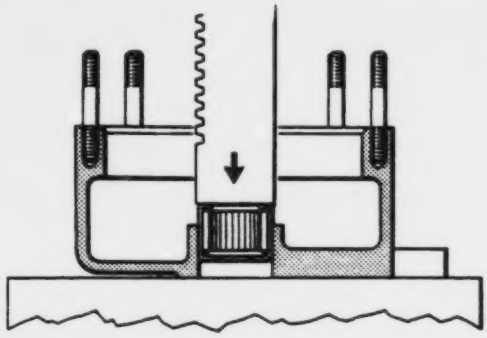


Figure No. 4.7 - Pressing Roller Bearing into Gear Case

17. Assemble the gear case (35) to the air motor assembly using twelve screws (36) and lockwashers (37). (On gas operated starters, the twelve lockwashers are replaced by seal washers).

NOTE: It may be necessary to rotate the air motor sleeves in either direction to properly align the bolt holes in the sleeve with those in the gear case cover. This can be done by inserting two cap screws 180 degrees apart in the rear of the sleeves and turning the sleeves by use of a screwdriver between the two cap screws.

18. Torque the twelve gear case cap screws (36) to 150 - 165 in.-lbs. (16.9 to 18.6Nm)
19. Press the single row rotor shaft bearings (6) into the rear endplates (3) as shown in Figure No. 4.8.

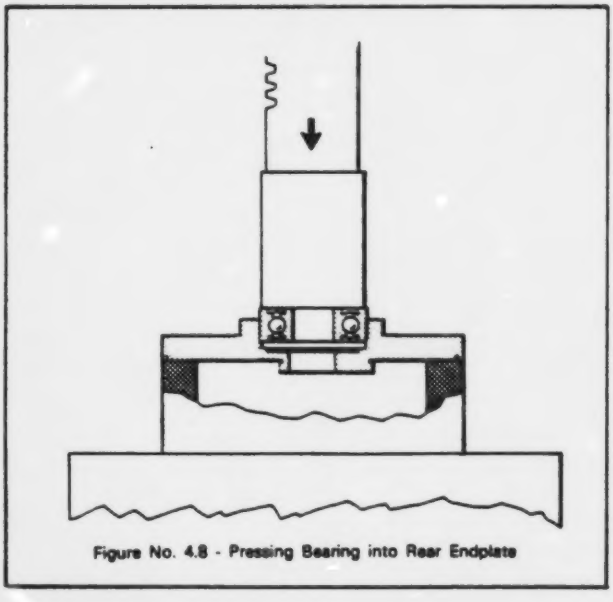


Figure No. 4.8 - Pressing Bearing into Rear Endplate

20. Install new endplate seals (2) on the rotor endplates (3).
21. Stand the air motor and gear case assembly on the gear case end.
22. Insert five new rotor blades (30) into each air motor (29).

NOTE: The rotor blades must stand squarely on end to permit assembly of the positive blade displacement cam which is part of the rear endplate.

23. Assemble the rear endplates (3) to the air motor assembly using six endplate screws (5) and lockwashers (4). (On gas operated starters, the lockwashers are replaced by seal washers and all mounting screws should be coated with Loctite #277).

NOTE: If the starter is equipped with an exhaust adapter, assemble the endplates and adapter to the air motor assembly using four exhaust adapter screws [22] with seal washers [*] and seals [20], and one exhaust adapter seal [19] as depicted in Fold-Out No. 3.

24. Torque the twelve endplate screws on the rear of the air motor to 150 - 165 in.-lbs. (16.9 to 18.6Nm).
25. Install a new bearing cover gasket (7) on each rear endplate (3).
26. Assemble the bearing covers (8) to the motor endplate with four cap screws (10) and lockwashers (9).
27. Torque the screws to 25 - 30 in.-lbs. (2.8 to 3.4 Nm).
28. Rotate each air motor by its pinion to insure that it is free and that the blades do not bind.

NOTE: Reassembly of the air motor group is now complete.

SECTION V - REASSEMBLY OF DRIVE GROUP

V-1. SAE #3 TYPE FLANGE

Reassembly of the drive group can be accomplished by referring to Fold-Out No. 1 and the following instructions:

1. Press a new seal (14) into the gear case cover (12), as shown in Figure No. 5.1.
2. Press a new drive shaft bearing (15) onto the output drive shaft (9), as shown in Figure No. 5.2.
3. Press the drive shaft bearing and shaft into the gear case cover (12), as shown in Figure No. 5.3.
4. Insert the drive shaft gear key (11) into the shaft (9) and orient the drive shaft gear (16) to the shaft and key. Press the gear onto the drive shaft, as shown in Figure No. 5.4.

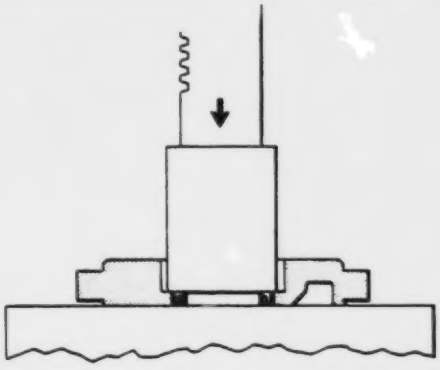


Figure No. 5.1 - Pressing Seal into Gear Case Cover

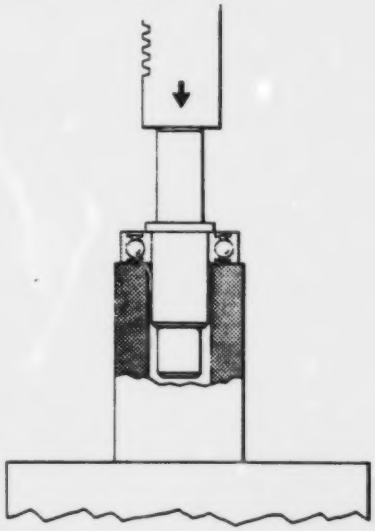


Figure No. 5.2 - Pressing Bearing into Drive Shaft

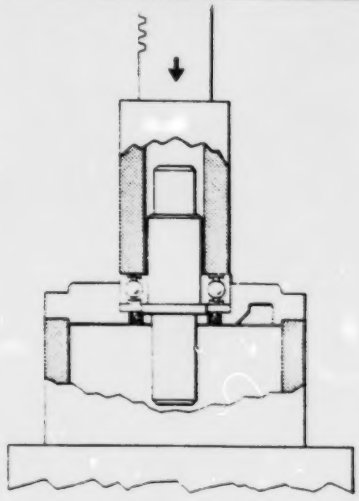


Figure No. 5.3 - Pressing Drive Shaft and Bearing into Gear Case Cover

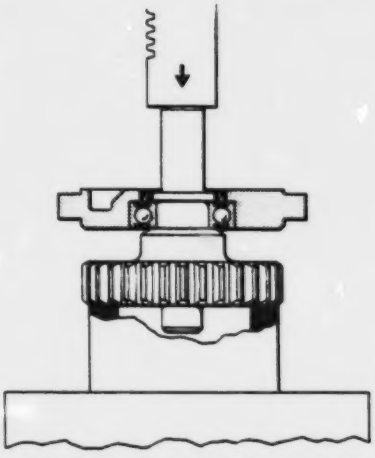


Figure No. 5.4 - Pressing Drive Shaft Gear onto Drive Shaft

5. Pack the interior of the gear case housing with ½ pound (.232 kg) of Lithium base general purpose grease. Insure that sufficient grease is packed around the air motor pinions. Lubricate the drive shaft roller bearing but do not fill completely with grease.
6. Lubricate both sides of the drive shaft thrust bearing (17) and assemble over the drive shaft into the gear.
7. Install a new gear case cover seal (13).
8. Locate the scribe mark previously placed on the outside of the gear case cover and align it with the scribe mark on the gear case housing. Insert the drive gear and cover assembly into the gear case as shown in Figure No. 5.5. It may be necessary to rotate one or both air motors to achieve alignment of the gears.

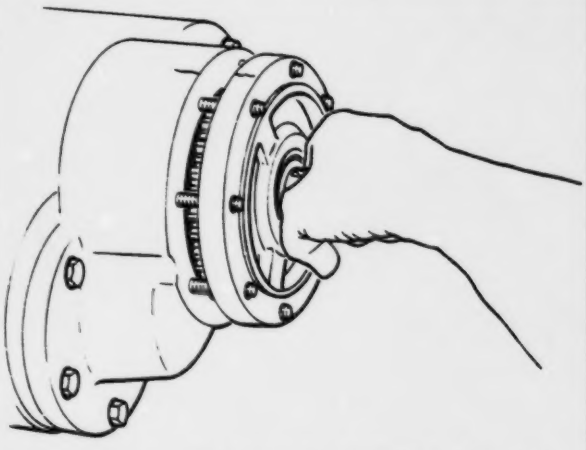


Figure No. 5.5 - Inserting Drive Shaft Assembly into Gear Case

9. Insert the thrust spring (8) into the drive shaft end of the Bendix drive unit (7).
10. Insert the drive unit keys (10) into the output end of the drive shaft (9).
11. Align the drive unit keyway with the drive shaft keys and slide the unit onto the drive shaft.
12. Turn the locking screw in until it bottoms in the drilled hole in the output drive shaft. Back the screw out sufficiently to orient the slot in the screw perpendicular to the drive shaft centerline.
13. Using needle nose pliers or a screwdriver, place the retaining snap ring over the drive shaft locking screw so that the retaining ring lies in the screwdriver slot.
14. Stand the drive housing (4) on the outboard bearing end in an arbor press and press the inside seal (3) into the outboard bearing bore, as shown in Figure No. 5.6.

NOTE: This seal must be pressed in so that it is flush to .010" [.25mm] below the machined surface on the inside of the drive housing.

15. Stand the drive housing on the flange end, as shown in Figure No. 5.7 and press in a new outboard drive bearing (2).
16. Press in the outside drive housing seal (1).
17. Lubricate the interior of the outboard drive bearing (2) with Lithium based general purpose grease.
18. Locate the scribe marks previously placed on the drive housing and orient the mark with those previously aligned on the gear case and cover.
19. Assemble the drive housing over the drive assembly by simultaneously aligning the outboard shaft and bearing and the eight drive housing mounting studs.
20. Assemble the eight drive housing nuts (5) and washers (6) to secure the drive housing assembly to the gear case cover. Torque the nuts to 150 - 165 in.-lbs. (16.9 to 18.6Nm).
21. Rotate the drive unit to insure that the drive assembly, gear case assembly and air motors are free.

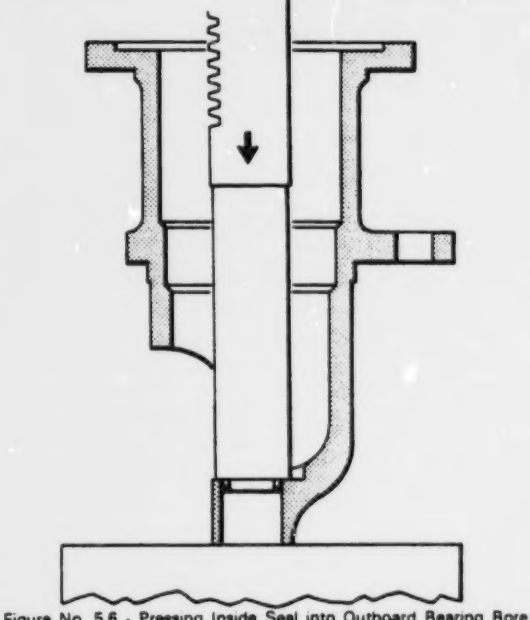


Figure No. 5.6 - Pressing Inside Seal into Outboard Bearing Bore

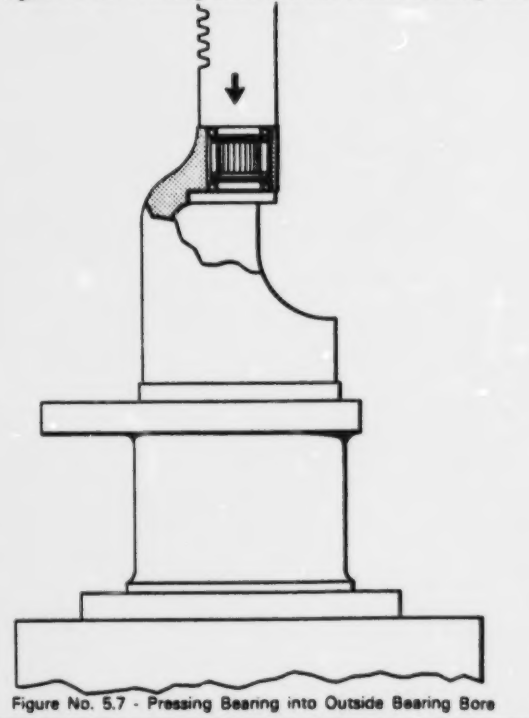


Figure No. 5.7 - Pressing Bearing into Outside Bearing Bore

V-2. SPECIAL THREE BOLT TYPE FLANGE

Reassembly of the drive group can be accomplished by referring to Fold-Out No. 2 and the following instructions:

1. Reassembly of the special three bolt drive housing is identical to Steps 1 through 8 in Section V-1. After completing Steps 1 through 8, proceed as follows:
2. Align the reference marks scribed on the gear case cover (12) and gear case and install the cover using eight socket head cap screws (18) and lockwashers (19). Tighten the cap screws to 180 to 210 in.-lbs. (20.3 to 23.7Nm).
3. Lubricate the drive unit spacer (10) with Lithium general purpose grease and install the spacer over the output shaft (9).
4. Stand the drive housing (4) on the outboard bearing end in an arbor press and press the inside seal (3) into the outboard bearing bore, as shown in Figure No. 5.8.

NOTE: This seal must be pressed in so that it is flush to .010" [.25mm] below the machined surface on the inside of the drive housing.

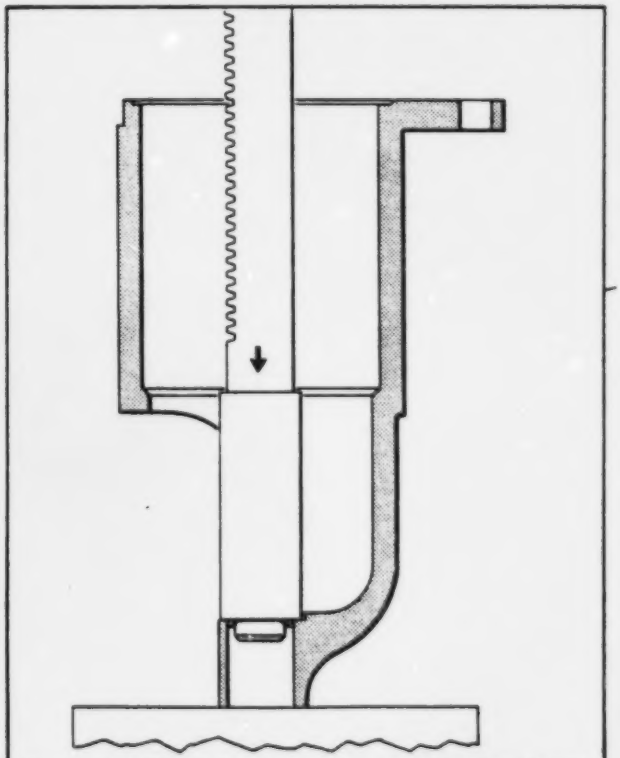


Figure No. 5.8 - Pressing Inside Seal into Outboard Bearing Bore (Special Three Bolt Type Flange)

5. Stand the drive housing on the flange end and press in the outboard drive bearing (2) and the outside seal (1). See Figure No. 5.9.
6. Lubricate the roller bearing (2) with Lithium base general purpose grease.
7. Apply a light coating of the Lithium base grease to the drive unit thrust washer (8) and install the washer over the drive shaft.
8. Assemble the drive unit (7) to the output shaft (9).
9. Assemble the drive housing (4) to the gear case cover and align the reference marks scribed earlier.
10. Install the six drive housing socket head cap screws (5) and washers (6) and tighten to 180 to 210 in.-lbs. (20.3 to 23.7Nm).
11. Rotate the drive unit by hand to insure that the drive assembly, gear case and air motors are free and not binding.

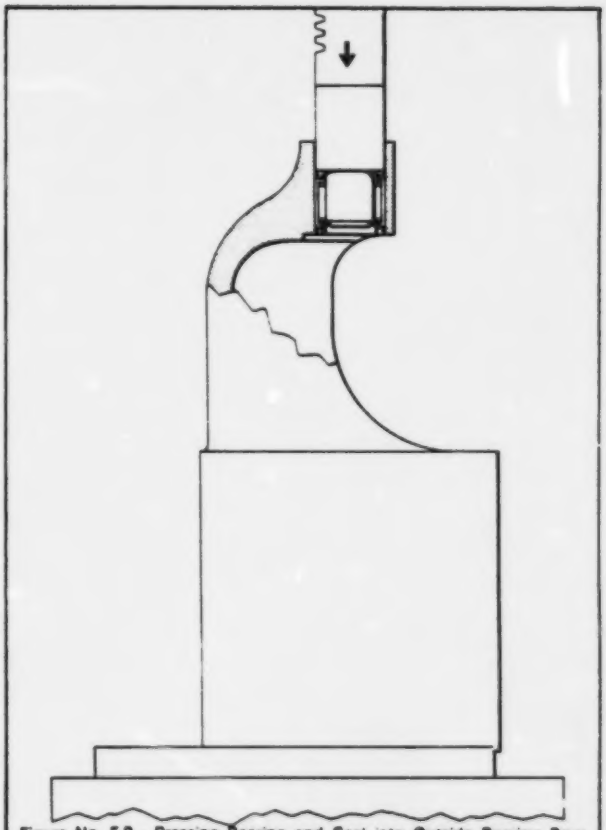


Figure No. 5.9 - Pressing Bearing and Seal into Outside Bearing Bore (Special Three Bolt Type Flange)

SECTION VI - STARTER MODEL CONVERSION AND REPHASING

The SM500 Series of air starters contains several different models. Each is designated by a particular part number and conversions from one model to another may be made by interchanging or replacing various parts. Consult the latest specification sheet to determine which parts should be substituted or if any housing position changes are necessary.

MOTOR ROTATION

Air motor rotation may be determined by viewing the inlet position of the air motor sleeves, as seen through the air inlet port in the motor casing. If the sleeves are installed so as to duct the inlet air to the right as viewed from the rear of the air motor (See Figure No. 6.1), the air motors will rotate clockwise. Right-hand rotation of the pinion will result due to the reduction gears changing rotational direction in the gear case assembly.

To reverse direction of the SM500, it will be necessary to completely disassemble the starter and reinsert the sleeves to change direction of the inlet air flow. In addition, the Bendix drive unit must also be changed to one with the opposite rotation.

Follow the instructions set forth in Sections II through V to achieve reversal of starter rotation.

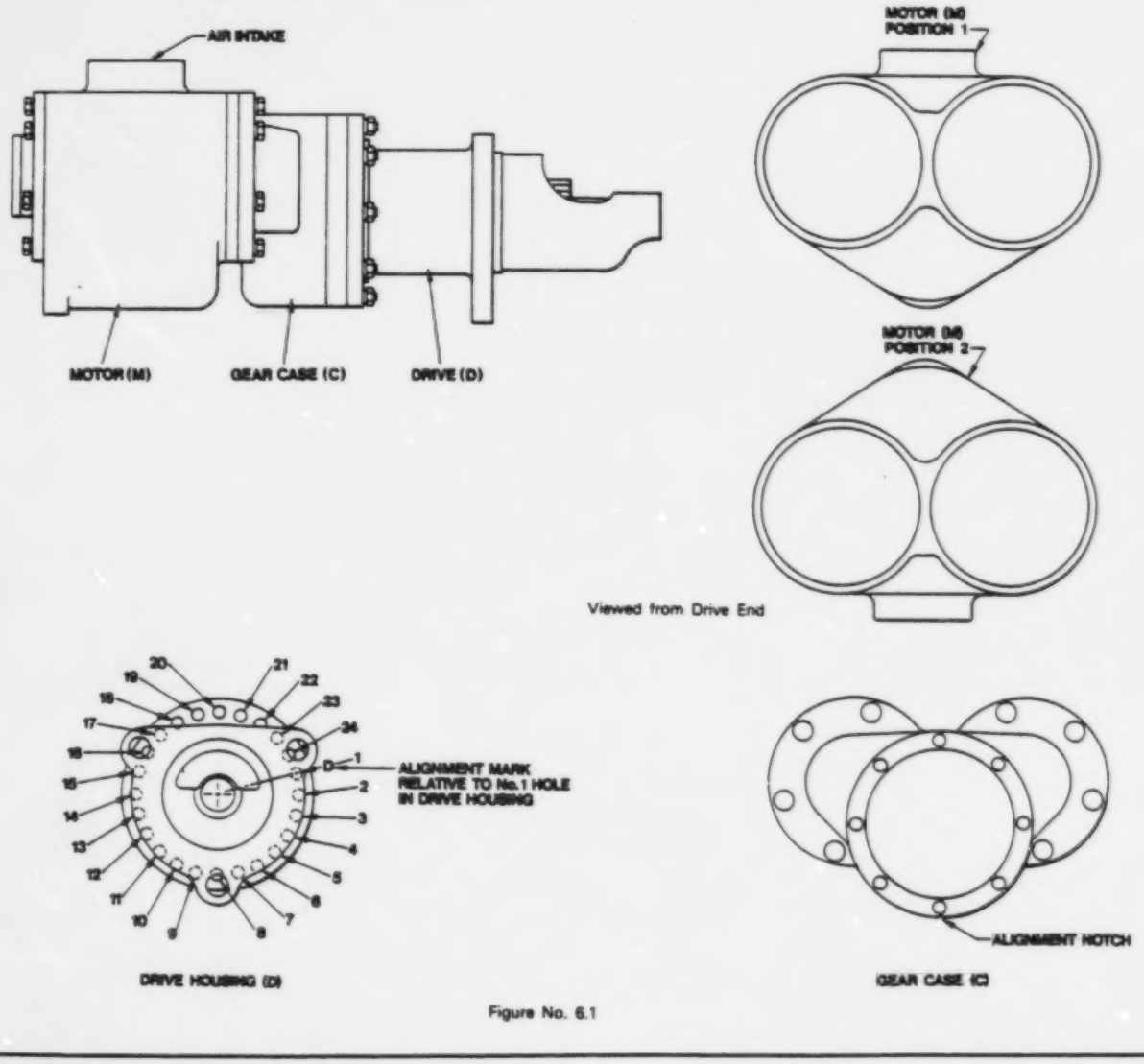


Figure No. 6.1

SERIES SM500 ASSEMBLY CODE

All Series SM500 assembly codes consist of five symbols (See Figure No. 6.2). Use of the code during reassembly or starter buildup, will insure that the starter will fit the application without any further modifications when the starter is installed on the engine.

EXPLANATION OF CODE

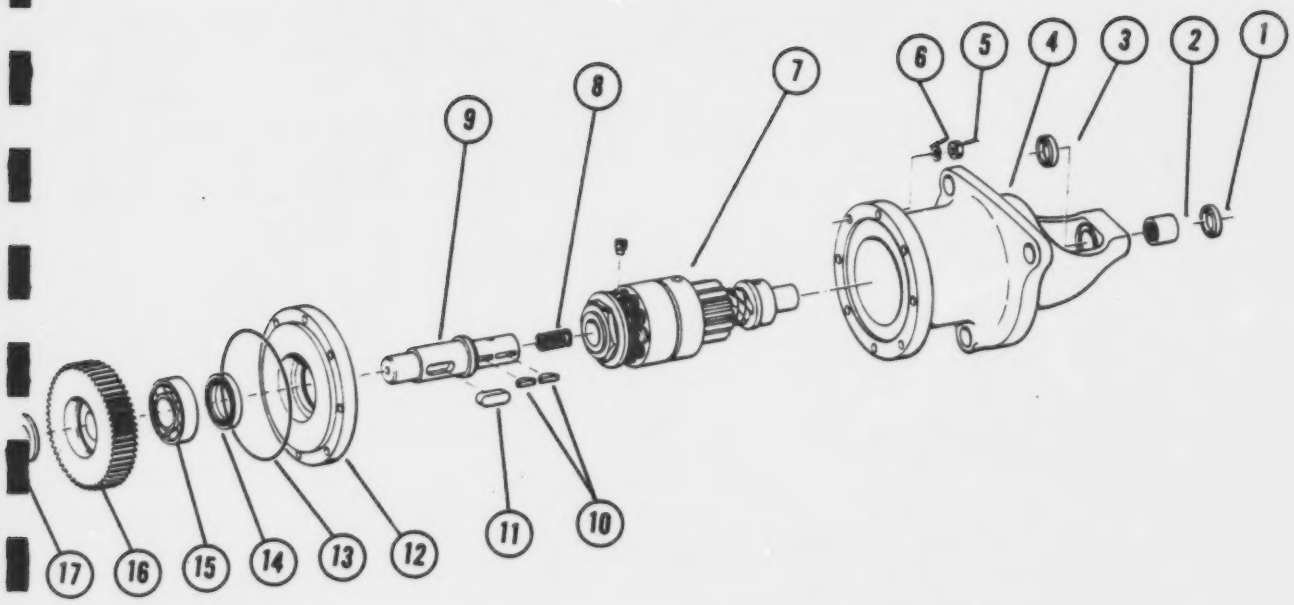
EXAMPLE: CODE M2CD7

M2 - Motor is inverted. Air inlet is below starter.

C - Gear case alignment notch.

D7 - Hole D7 to be assembled to stud at alignment notch.

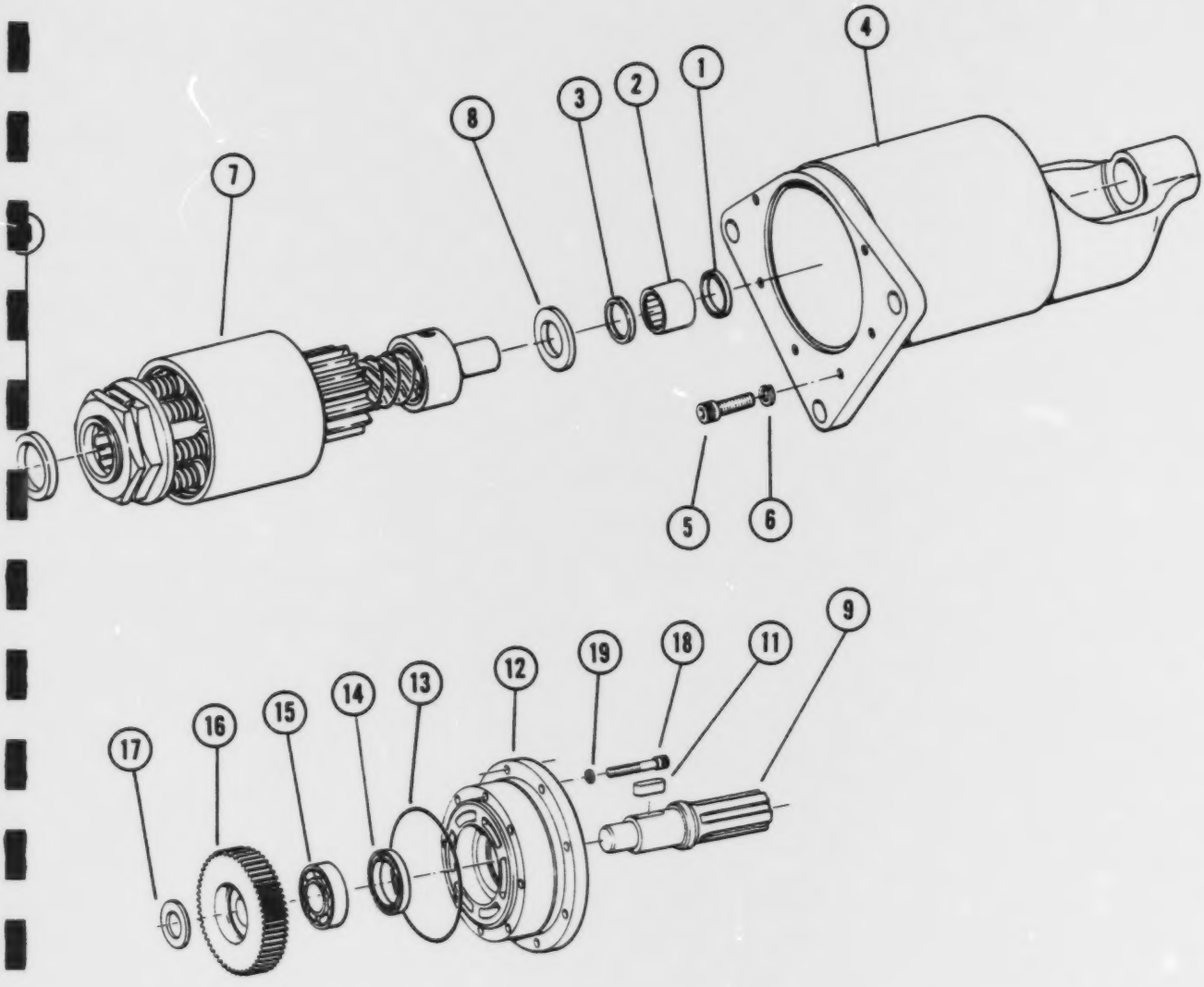
Figure No. 6.2



FOLD-OUT NO. 1

FOLD-OUT NO. 1 - KEY SHEET

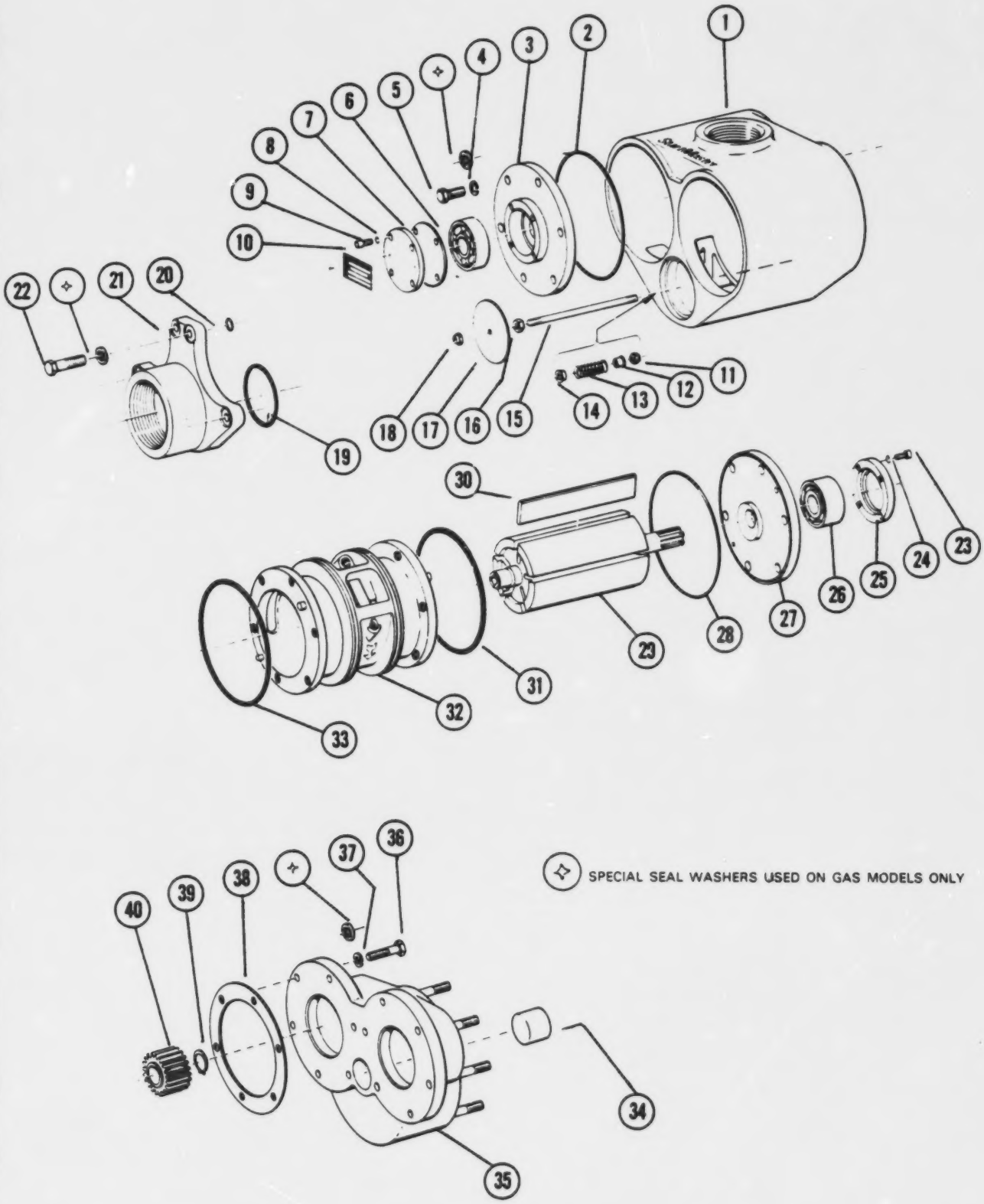
1 SEAL - DRIVE HOUSING
2 BEARING - DRIVE UNIT
3 SEAL - DRIVE HOUSING
4 HOUSING - DRIVE
5 NUT - DRIVE HOUSING
6 WASHER - DRIVE HOUSING
7 DRIVE UNIT - BENDIX
8 SPRING - DRIVE UNIT
9 SHAFT - DRIVE
10 KEY - DRIVE SHAFT
11 KEY - GEAR
12 COVER - GEAR CASE
13 SEAL - GEAR CASE
14 SEAL - DRIVE SHAFT
15 BEARING - DRIVE SHAFT
16 GEAR - DRIVE SHAFT
17 BEARING - THRUST



FOLD-OUT NO. 2

FOLD-OUT NO. 2 - KEY SHEET

1 SEAL - DRIVE HOUSING
2 BEARING - DRIVE UNIT
3 SEAL - DRIVE HOUSING
4 HOUSING - DRIVE
5 NUT - CAP SCREW
6 WASHER
7 DRIVE UNIT- BENDIX
8 WASHER - THRUST
9 SHAFT - DRIVE
10 SPACER - DRIVE UNIT
11 KEY - GEAR
12 COVER - CEAR CASE
13 SEAL - GEAR CASE
14 SEAL - DRIVE SHAFT
15 BEARING - DRIVE SHAFT
16 GEAR - DRIVE SHAFT
17 BEARING - THRUST
18 SCREW - GEAR CASE
19 LOCKWASHER - GEAR CASE



SPECIAL SEAL WASHERS USED ON GAS MODELS ONLY

FOLD-OUT NO. 3

FOLD-OUT NO. 3 - KEY SHEET

1 CASING - AIR MOTOR
2 SEAL - ENDPLATE
3 PLATE - END
4 LOCKWASHER
5 SCREW - ENDPLATE
6 BEARING - ROTOR SHAFT
7 GASKET - BEARING COVER
8 COVER - BEARING
9 LOCKWASHER - BEARING RETAINING
10 SCREW - BEARING RETAINING
11 NUT - EXHAUST VALVE
12 GUIDE - EXHAUST VALVE SPRING
13 SPRING - EXHAUST VALVE
14 GUIDE - EXHAUST VALVE SPRING
15 SHAFT - EXHAUST VALVE
16 NUT - EXHAUST VALVE JAM
17 PLATE - EXHAUST VALVE
18 NUT - EXHAUST VALVE
19 SEAL - EXHAUST ADAPTER
20 SEAL - EXHAUST ADAPTER
21 ADAPTER - EXHAUST
22 SCREW - EXHAUST ADAPTER
23 SCREW - BEARING RETAINING
24 LOCKWASHER - BEARING RETAINING
25 RETAINER - BEARING
26 BEARING - ROTOR SHAFT
27 PLATE - END
28 SEAL - ENDPLATE
29 ROTOR ASSEMBLY
30 BLADE - ROTOR
31 SEAL - AIR MOTOR SLEEVE
32 SLEEVE ASSEMBLY - AIR MOTOR
33 SEAL - AIR MOTOR SLEEVE
34 BEARING - DRIVE SHAFT
35 CASE ASSEMBLY - GEAR
36 SCREW - GEAR CASE
37 LOCKWASHER
38 GASKET - GEAR CASE
39 RING - PINION RETAINING
40 PINION - ROTOR

HOW TO USE THE CHASSIS & ENGINE SECTIONS OF THIS CATALOG

TO SAVE YOU TIME

This Parts Catalog is a means of identifying any part, or assembly of parts, by the use of a catalog number, word, letter or symbol co-ordinated with a picture or sketch for visual recognition

It is engineered to save time and money in ordering parts and affords an easy and accurate method of identifying the correct parts for the equipments covered.

A few minutes spent in studying it's overall arrangement will save time in locating ordering data.

KEEP YOUR CATALOGS UP-TO-DATE

After furnishing the initial catalog, "MLW" will continue to provide up-to-date ordering data. When changes occur, parts bulletins will be revised and distributed. The superseded bulletin should be removed, destroyed, and the new bulletin inserted. Your prompt action will insure up-to-date ordering data.

TO IDENTIFY PROPER BULLETIN

Your Parts Catalog is made up of the index and a complete set of Bulletins covering your Diesel engine and/or locomotive. Each bulletin is numbered and covers a particular subassembly.

Determine from the index the bulletin covering the assembly for which the replacement part is required. The applicable parts bulletin is listed opposite each device. The bulletins are filed in numerical sequence following the index pages.

You may find in the index that several bulletins may be listed for the same assembly which will indicate that you must ascertain the Diesel engine order number or the Sales order number, as well as the Diesel engine number and furnish this information when ordering replacement parts.

To help you locate a part, reference numbers (Ref. No.) are used on the illustration, and also in the left-hand column of the Parts List. Reference numbers are not used for ordering parts but only to identify the part on the illustration and then to locate that part in the Catalog.

WHAT THE CATALOG NUMBER TELLS YOU

22200213-1 (Cylinder Head Assembly)
2 22 0 0213-1

First Digit: Engine or Chassis Classification.

If the first digit is a:

"1" or "9", the part is a chassis part.
"C", the part is a chassis part for a locomotive with 539 engine.
"2", the part is for a 244 or 251 engine (in the case of commercial hardware items it may also be applicable to 539 engines).
"5", the part is for the 539 engine.

Second and Third Digits: Functional Group Number.

For "all" Engine and Chassis Parts the second and third digits tell in which functional group the part belongs. The list of Group Numbers used are listed on the next page.

Fourth Digit: Assembly or Single Part.

If the fourth digit is "0" the parts is an assembly, whereas if it is other than "0" it is a single part. (This rule does not apply to catalog numbers starting with "C", or to those which start with a 5 and end with a letter; e.g., A, B, C, etc.)

Remaining Digits "Before" The Dash (-):

These digits are the part identification numbers.

The Digit "After" The Dash (if any): Supersedures

If, whenever a part is modified, the new part can be interchanged with the old part, the modified part is identified with a digit after the dash.

If a part is modified several times, but can still be used in place of the older parts, the successive changes are indicated by adding "-1", "-2", "-3", etc. after the dash. With this system, proper stock rotation is insured through first disbursing the older modifications.

If a part is modified, but is not interchangeable with the old part, the catalog number is completely changed.

The above supersedure rules do not apply to catalog numbers starting with a "C", or to those starting with a "5" and ending with a letter (A, B, C, etc.). For these old type numbers, if the part is modified but still interchangeable with the older part, the catalog number is not changed. If the modified part is not interchangeable the catalog number is changed.

PARTS "GROUP NUMBERS"

(The second and third digits of the catalog number indicate the group in which the part belongs)

Group No.	Diesel Engine Parts	Chassis Parts
10	Engine mounted air compressor	
11		Axle - Axle End Caps - Collars
12		Bells and details
14	Main base, Main bearings, End casings	
15	Miscellaneous Standards (Gaskets, bolts, nuts, etc.)	Miscellaneous Standards (Bolts, nuts)
16	Timing Mechanism, Camshaft and Casing	Side Frames
17	Connecting Rod, Bearings, Caps and Bolts	Motor Truck Boxes and details
18	Marine Manuevering Gear and Air Starting	Brackets, Stands and Gauge Boards
19	Crankshaft System, Oil Seals, Generator Adapter	Air Compressor, Brake Equipment (Operating)
20		Truck and Hand Brake details
21	Cylinder Liners and Water Jackets	
22	Cylinder Heads	Cab and Hood Assemblies
23	Air and Exhaust Valves, Fuel Injection Nozzle and Holder	Cab details
24	Cylinder head valve levers, valve lever casings and brackets, crosshead casings and push rods	Cab details
25	Water Pumps	Cocks and Valves
26	Turbochargers	Cocks and Valves
27		Sight Gauges and details
28	Air and Exhaust Manifolds	Oil Cut-out Rigging
29	Engine Turning Device	
31	Cylinder Blocks, Covers and Main Bearing Caps	
32	Fuel Injection Pumps, Fuel Oil Filters, and Fuel Injection Linkage	
34	Gauges on Engines, Name Plates and Decals	
35	Gears	
36	Governors, Gov. Tachometer Drive	
37		Couplers, Drawgear and details
39	Lubricating Oil Pumps and Drive	
40	Piping and Fittings	Motor Truck arrangement
41		Motor Truck details
42	Main Pistons, Piston Pins and Rings	
44		Exhaust Stack
46	Springs	
47	Tools	
49	Fuel Booster and Governor Lube Oil Pump Assy. and Pressure Regulating Valves	
50	Gasket Sets and Miscellaneous Kits	Miscellaneous Kits
53		Handrails and Steps
54		Headlights, Lamps, Number Plates and Signal Attachments
59		Electrical Equipment other than Propulsion
60		Oiling arrangements
62		Pilots and details
63		Pipe, Hose and Fittings
64		Piping, Cab Heater and Miscellaneous
67		Radiators, Cooling Equipment, and Auxiliary Drives
73		Sand Boxes and details
76		Springs
79		Pressure Gauges

Determine from the bulletin the following data for each part required:

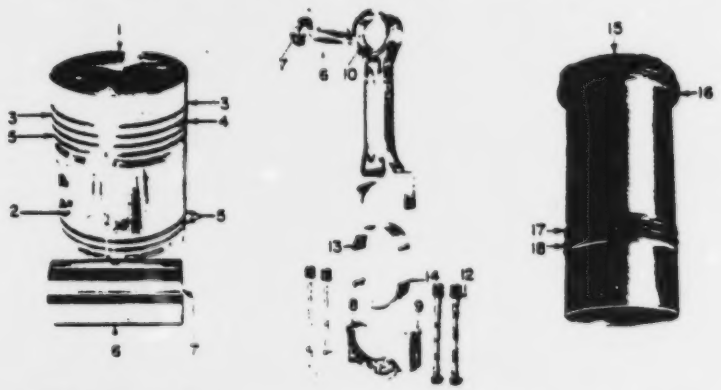
A - Part Number

B - Quantity

C - Description

This will help you to double check your order. These items, Part Number, Quantity and Description should be included in your order for parts.

PISTON, CONNECTING ROD AND CYLINDER LINER



Ref. No.	Part No.	No. Req.	Description
1	2420043-1	1	Piston
	21327SS-1	2	Ring, snap, piston pin retaining
2	16393716	1	Pipe plug, 1/8 IPS, sq. h.
	2420081	1	Ring, piston set
3	2421088-2	2	Ring, piston, compression (square face)
4	2421089-1	1	Ring, piston, compression (taper face)
5	24310810	3	Ring, piston, scraper
6	2420081-3	1	Pin, piston, with sleeve
7	2421071	1	Sleeve, piston pin
	2170016-1	1	Rod, connecting, with cap and bushing
8	21511034	1	Dowel, cap to rod, 3/8 dia. x 5/8
9	21511041	1	Dowel, cap to rod, 3/8 dia. x 7/8
10	2171015	1	Bushing, piston pin
11	2171062	4	Bolt, cap to rod, spl.
12	2151021	4	Nut, rod bolt, spl.
	2151409	4	Pin, cotter, nut locking, 1/8 dia. x 1-1/2
13	21710226	1	Shell, bearing, in rod
14	21710228	1	Shell, bearing, in cap
15	22110115	1	Liner, cylinder (chrome plated)
16	2151452	1	Gasket, liner to block (top)
17	2151456	1	Gasket, liner to block (center)
18	2151455-1	1	Gasket, liner to block (bottom)

Group No.	Diesel Engine Parts	Chassis Parts
83		Tanks and details
95		Wheels and Tires
96		Air Horns and details
97		Turbocharger Air Filter and Throttle Rigging
99		Pulleys, Bolts, Belts, Speedometer Drive Assemblies, Mounting and Miscellaneous

INDENTIONS

Indentions are used in the description of parts to indicate in what assemblies or subassemblies parts may be procured. On an order for an assembly, all of the parts indented under it will be supplied. For example, an order for one 2321334-2 Housing will procure all the indented items following it; bushing for housing and barrel locating pin, assembled. An order for 2322162 will procure only the bushing, as there are no parts indented under it.

Ref. No.	Cat. No.	No. Required	Description
			FUEL INJECTION PUMP (Bosch APF-1CC-170T-1832A, B or C)
	2320012-4	16	Fuel injection pump
560A	2321263-2	16	Plunger and barrel
561A	2321334-2	16	Housing
561B	2322162	32	Bushing for housing
561C	2321383	16	Pin, barrel locating
562A	2321345-1	16	Holder, delivery valve
563A	2322131	32	Gasket, baffle screw
564A	2322141-1	32	Screw, baffle
565A	2321365-1	16	Delivery valve

STANDARD HARDWARE

Wherever size of standard hardware items such as capscrews, nuts, lockwashers, washers, cotter pins, dowel pins, etc., are shown in our DRP bulletins, such parts are not special in any way and we furnish the dimensions to assist our customer in procuring them either from their local supplier or their own stores stock. The material is always steel unless otherwise stated.

FUEL INJECTION TUBE

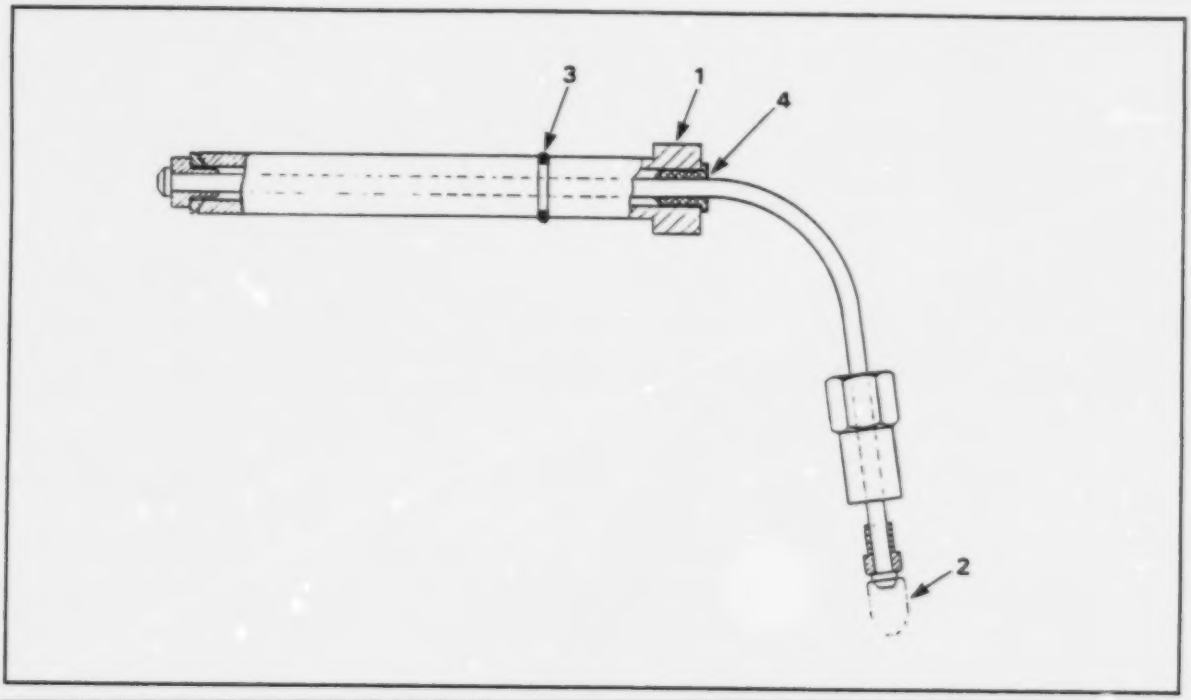


Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	4401031-1	1	Tube, fuel injection
	2	2402466	1	Valve, snubber
	3	2402861-1	1	O-ring, injection tube to cylinder head
	4	* 8152031	1	Support, injection tube (2 piece)

* Added or changed since last issue.

Data subject to change without notice.

MODEL DIFFERENCE SHEET

FUEL INJECTION EQUIPMENT PARTS

The purpose of this Model Difference Sheet is to identify procedures that differ from those shown in your Parts Catalogue.

Please retain this MDS with DRP-16040.

The parts in this Publication related to the fuel injection pumps are not applicable to your engine. Refer to Bryce Publication No. 79, issue 1 (12.80) for parts.

Data subject to change without notice.

FUEL INJECTION EQUIPMENT

Fuel Pumps ---------- Pg. 2

Nozzle & Holder, 145° ---------- Pg. 4

Nozzle & Holder, 160° ---------- Pg. 5

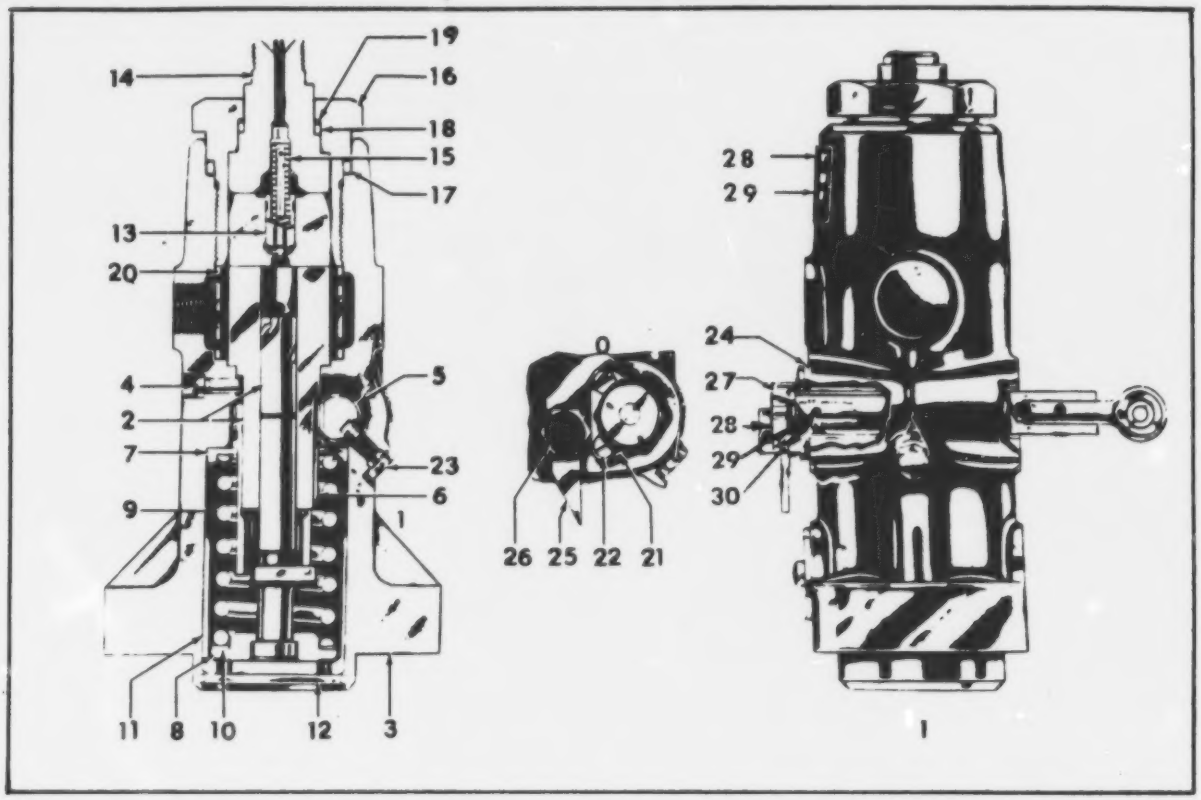
Nozzle & Holder, 157° ---------- Pg. 6

Tube, Fuel Injection ---------- Pg. 7

Inlet, Fuel Injection Pump -------- Pg. 8

This parts bulletin lists all Fuel Injection Equipment Alco currently offers on a Renewal Parts basis. To properly identify the specific equipment for your engine(s), you should refer to your parts catalog index.

PUMP, FUEL INJECTION

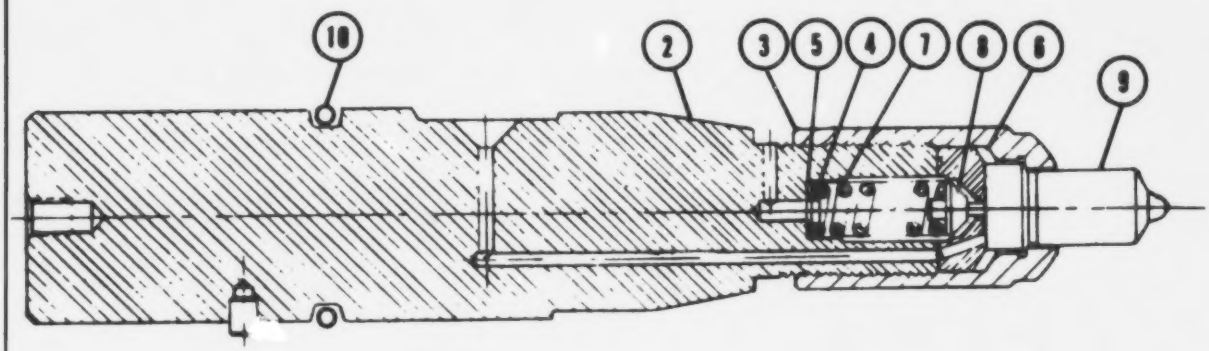


Ref. No.	Part No.	No. Req'd.			Description
1	2320016-3	1	-	-	Pump, fuel injection (15 mm)
1	4320021-1	-	1	-	Pump, fuel injection (17 mm)
1	23200127	-	-	1	Pump, fuel injection (18 mm)
2	2321267	1	-	-	Plunger & barrel (15 mm)
2	23212610	-	-	-	Plunger & barrel (16 mm)
2	4321091	-	1	-	Plunger & barrel (17 mm)
2	23212611	-	-	1	Plunger & barrel (18 mm)
3	2321338	1	1	1	Housing, pump
4	2321383-1	1	1	1	Pin, locating, plunger & barrel
5	2322164-1	2	2	2	Bushing, control rack
6	2321445-1	1	1	1	Sleeve, control
7	2321316	1	1	1	Seat, plunger spring, upper
8	2321304	1	1	1	Seat, plunger spring, lower
9	2322094-1	1	1	1	Spring, plunger
10	2322384	1	1	1	Washer, plunger spring
11	2321294-1	1	1	1	Cup, guide
12	2321464	1	1	1	Ring, snap, guide cup
13	23213611	1	-	-	Delivery valve
13	2321368	-	1	1	Delivery valve
14	2321349-1	1	1	1	Holder, delivery valve

Ref. No.	Part No.	No. Req'd.			Description
15	2321393	1	1	1	Spring, delivery valve
16	2321577	1	1	1	Nut, delivery valve holder
17	2321326-1	1	1	1	Gasket, "O" ring, nut to housing
18	2321327-1	1	1	1	Gasket, "O" ring, nut to delivery valve
19	2155085-1	1	1	1	Gasket, leather "O" ring to nut
20	2322652-2	1	1	1	Baffle ring
21	2321355	1	1	1	Pointer, rack control
22	21558144	2	2	2	Screw, rack pointer
23	2322105	1	1	1	Screw, stop, control rack
24	23210321	+	+	+	Shim, rack pointer, .005 in.
24	23210318	+	+	+	Shim, rack pointer, .0075 in.
24	23210322	+	+	+	Shim, rack pointer, .010 in.
24	23210323	+	+	+	Shim, rack pointer, .020 in.
24	23210324	+	+	+	Shim, rack pointer, .031 in.
24	23210325	+	+	+	Shim, rack pointer, .062 in.
24	23210319	+	+	+	Shim, rack pointer, .078 in.
24	23210320	+	+	+	Shim, rack pointer, .093 in.
25	2322662	1	1	1	Latch, control rack
26	2321554	1	1	1	Screw, latch
27	2321379	1	1	1	Control rack unit
28	2322642-1	1	1	1	Stop, adjustable
29	23210326	+	+	+	Shim, adjustable, rack stop, .005 in.
29	23210327	+	+	+	Shim, adjustable, rack stop, .0075 in.
29	23210328	+	+	+	Shim, adjustable, rack stop, .010 in.
29	23210329	+	+	+	Shim, adjustable, rack stop, .020 in.
29	23210330	+	+	+	Shim, adjustable, rack stop, .031 in.
30	2321387-1	1	1	1	Pin, rack stop
31	2321387-1	1	1	1	Pin, rack link
32	2322474	1	1	1	Link, control rack
	2321533	1	1	1	Cover, inspection window
	2322083	1	1	1	Gasket, for screw
	21558145	2	2	2	Screw, inspection window cover
	532209A	2	2	2	Gasket, for screw
	21513532-1	4	4	4	Capscrew, fuel pump to supp't.,1/2-13x2-1/4
	2151313-1	4	4	4	Lockwasher, 1/2

FUEL INJECTION NOZZLE AND HOLDER

145°



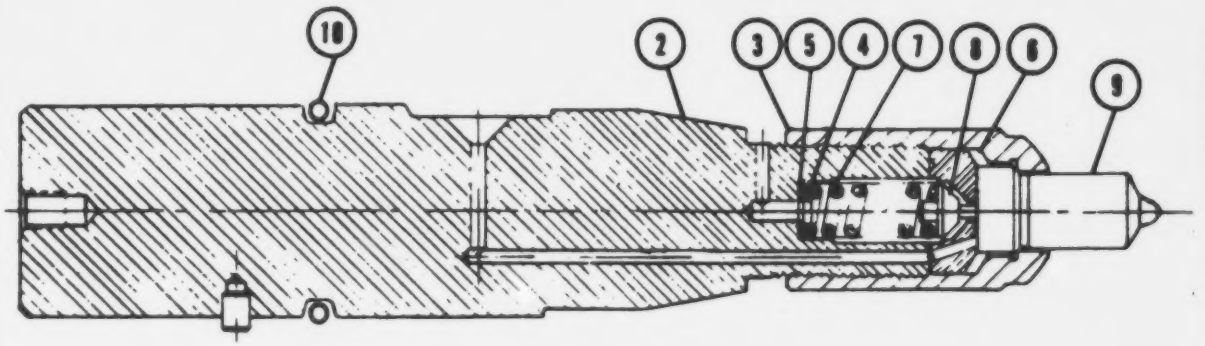
REF. 1

Ref. No.	Part No.	No. Req.	Description
1	22300130	1	Nozzle and Holder, .325 mm (see Index)
1	22300128	1	Nozzle and Holder, .350 mm (see Index)
1	22300124	1	Nozzle and Holder, .375 mm (see Index)
1	22300129	1	Nozzle and Holder, .400 mm (see Index)
	22312410-2	1	Holder, nozzle
2	2231278	1	Body, nozzle holder
3	22313310	1	Nut, nozzle cap
4	2231391	1	Spacer
5	2231411	+	Shim, upper spring seat, .002 thk.
	2231412	+	Shim, upper spring seat, .004 thk.
	2231413	+	Shim, upper spring seat, .008 thk.
	2231414	+	Shim, upper spring seat, .020 thk.
	2231415	+	Shim, upper spring seat, .042 thk.
6	2231402-1	1	Spacer, valve stop
7	2231295	1	Spring, pressure adjusting
8	22312610	1	Seat, spring, lower
9	22310230	1	Nozzle, 145°, .325 mm
9	22310227	1	Nozzle, 145°, .350 mm
9	22310224	1	Nozzle, 145°, .375 mm
9	22310226	1	Nozzle, 145°, .400 mm
10	2231453	1	"O" Ring, nozzle holder to cylinder head
	2221121-1	1	Strong back, nozzle holder to cylinder head
	2151429-5	2	Stud, special, nozzle clamp to cylinder head
	2151691-1	2	Nut high, 5/8-11

+ As required.

FUEL INJECTION NOZZLE AND HOLDER

160°



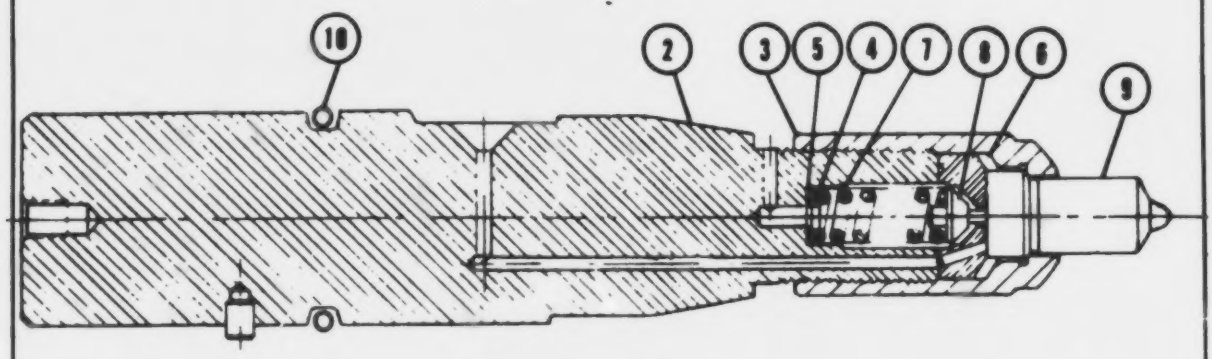
REF. 1

Ref. No.	Part No.	No. Req.	Description
1	22300134	1	Nozzle and Holder, .325 mm (see index)
1	22300133	1	Nozzle and Holder, .350 mm (see index)
1	22300132	1	Nozzle and Holder, .375 mm (see index)
1	22300131	1	Nozzle and Holder, .400 mm (see index)
	22312410-2	1	Holder, nozzle
2	2231278	1	Body, nozzle holder
3	22313310	1	Nut, nozzle cap
4	2231391	1	Spacer
5	2231411	+	Shim, upper spring seat, .002 thk.
	2231412	+	Shim, upper spring seat, .004 thk.
	2231413	+	Shim, upper spring seat, .008 thk.
	2231414	+	Shim, upper spring seat, .020 thk.
	2231415	+	Shim, upper spring seat, .042 thk.
6	2231402-1	1	Spacer, valve stop
7	2231295	1	Spring, pressure adjusting
8	22312610	1	Seat, spring, lower
9	22310234	1	Nozzle, 160°, .325 mm
9	22310233	1	Nozzle, 160°, .350 mm
9	22310232	1	Nozzle, 160°, .375 mm
9	22310231	1	Nozzle, 160°, .400 mm
10	2231453	1	"O" Ring, nozzle holder to cylinder head
	2221121-1	1	Srong back, nozzle holder to cylinder head
	2151429-5	2	Stud, special, nozzle clamp to cylinder head
	2151691-1	2	Nut high, 5/8-11

+ As required.

FUEL INJECTION NOZZLE AND HOLDER

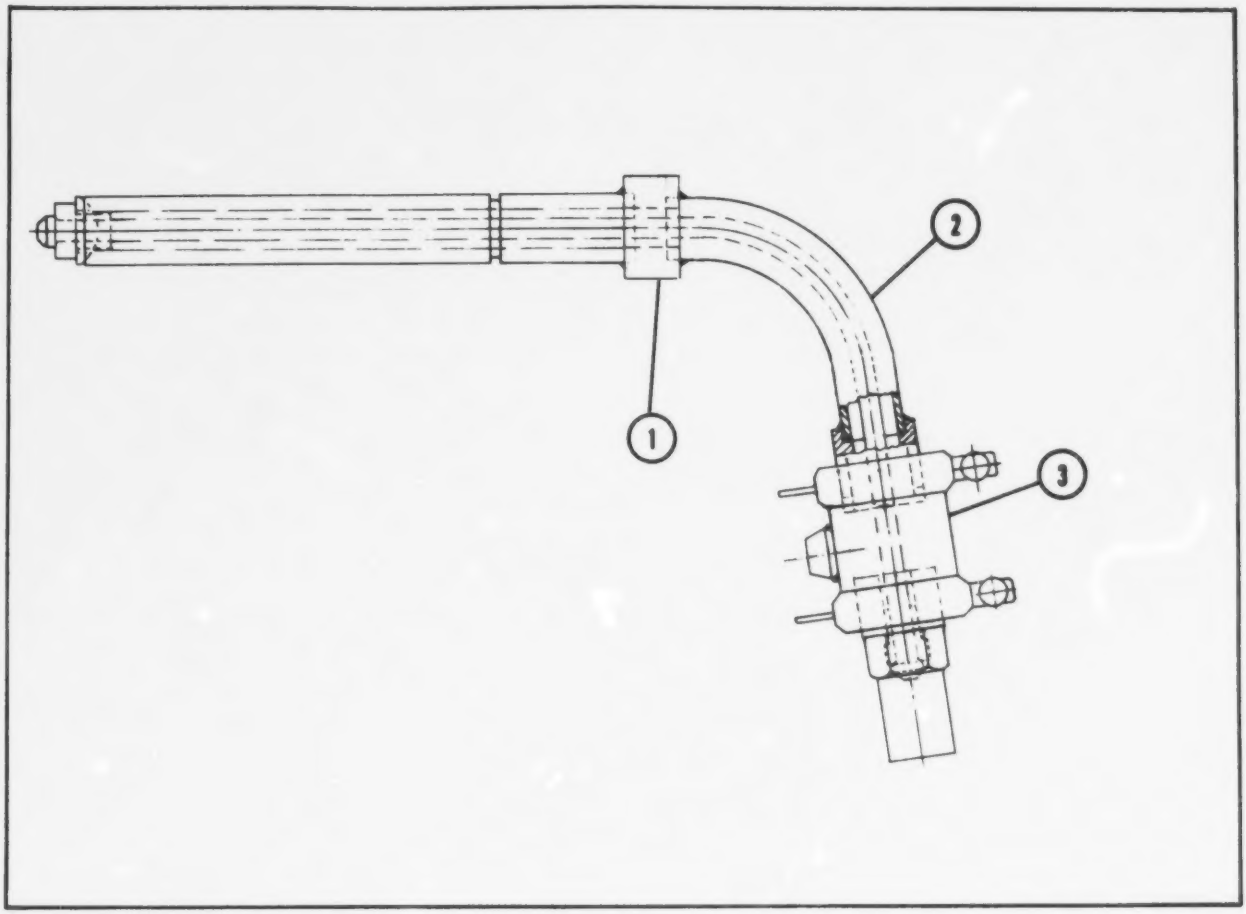
157°



REF. 1

Ref. No.	Part No.	No. Req.	Description
1	22300136	1	Nozzle and Holder, .325 mm (see index)
1	22300137	1	Nozzle and Holder, .350 mm (see index)
1	22300138	1	Nozzle and Holder, .375 mm (see index)
1	22300139	1	Nozzle and Holder, .400 mm (see index)
	22312410-2	1	Holder, nozzle
2	2231278	1	Body, nozzle holder
3	22313310	1	Nut, nozzle cap
4	2231391	1	Spacer
5	2231411	+	Shim, upper spring seat, .002 thk.
	2231412	+	Shim, upper spring seat, .004 thk.
	2231413	+	Shim, upper spring seat, .008 thk.
	2231414	+	Shim, upper spring seat, .020 thk.
	2231415	+	Shim, upper spring seat, .042 thk.
6	2231402-1	1	Spacer, valve stop
7	2231295	1	Spring, pressure adjusting
8	22312610	1	Seat, spring, lower
9	22310235	1	Nozzle, 157, .325 mm
9	22310236	1	Nozzle, 157, .350 mm
9	22310237	1	Nozzle, 157, .375 mm
9	22310238	1	Nozzle, 157, .400 mm
10	2231453	1	"O"Ring, nozzle holder to cylinder head
	2221121-1	1	Strong back, nozzle holder to cyl. head
	2151429-5	2	Stud, special, nozzle clamp to cyl. head
	2151691-1	2	Nut high, 5/8-11

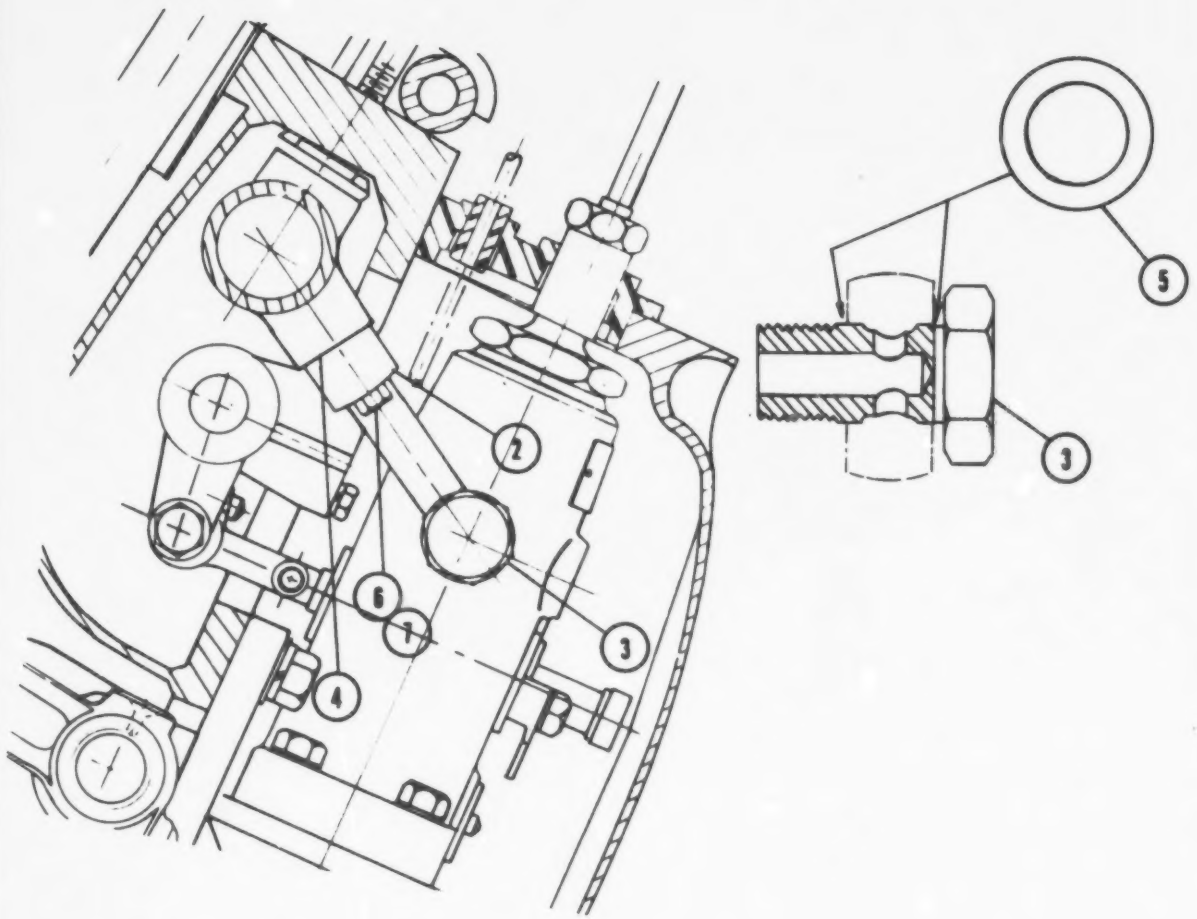
FUEL INJECTION TUBE



SHIELDED			
Ref. No.	Part No.	No. Req.	Description
1	24017012	1	Tube, fuel injection
2	24023675	1	Elbow, split
3	2402096	1	Clamp, elbow
	2402466	1	Valve, snubber
	2402861-1	1	"O" Ring, injection tube to cyl. head

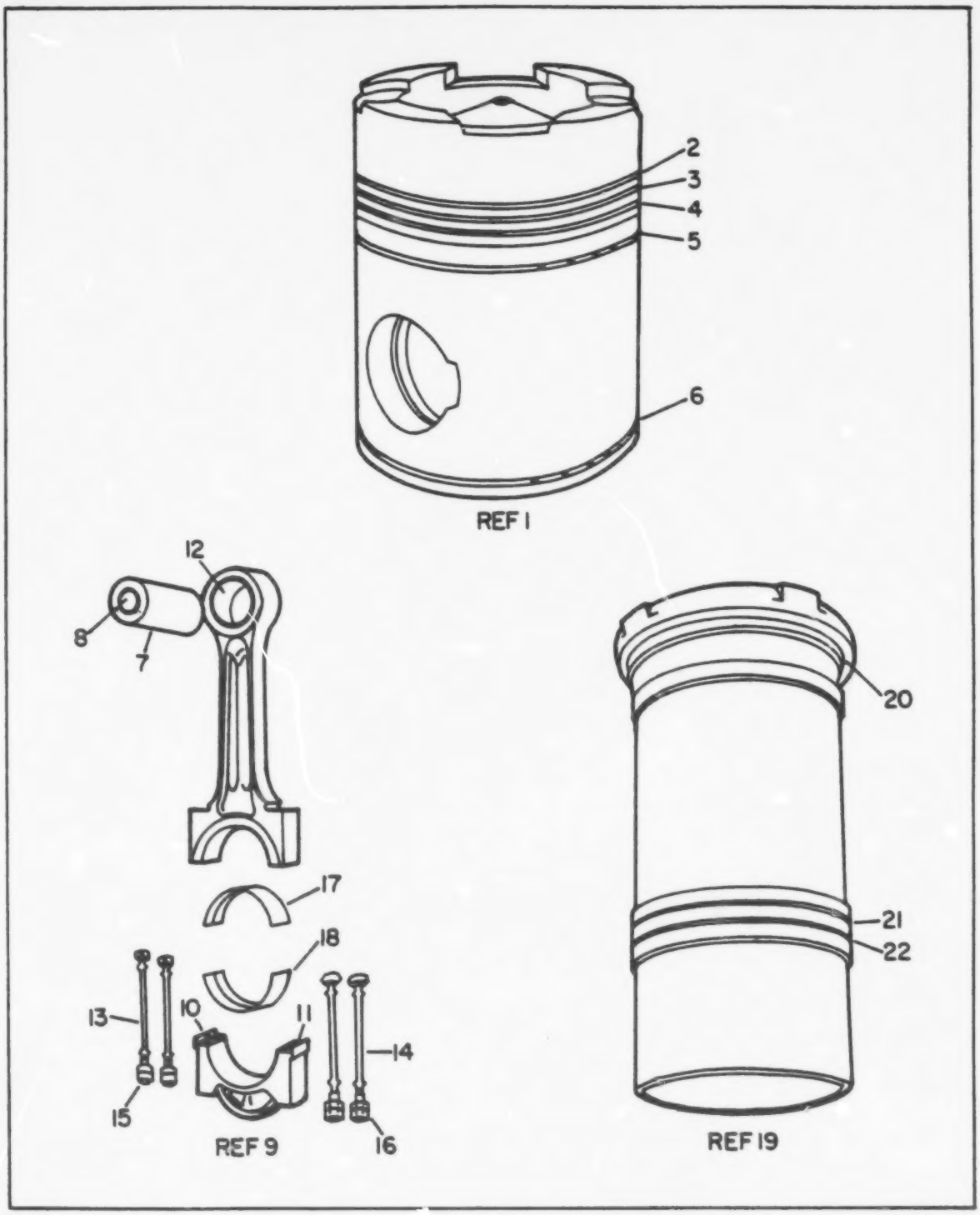
STANDARD			
	Part No.	No. Req.	Description
	4401031-1	1	Tube, fuel injection
	2402466	1	Valve, snubber
	2402861-1	1	"O" ring, injection tube to cyl. head

FUEL INLET TO FUEL INJ. PUMP CONNECTION



Ref. No.	Part No.	No. Req.	Description
2	2402442	1	Inlet, Fuel Injection Pump
3	2401442	1	Screw, Retaining, Inlet to Pump
4	2153595	1	Gasket, Inlet to Header ("0" Ring)
5	2153594	2	Gasket, Retaining Screw (Copper Washer)
6	2155942-1	2	Capscrew, Spl. Inlet to Header
7	21513129	2	Lockwasher, 3/8, Lubrited

PISTON, CONNECTING ROD AND CYLINDER LINER

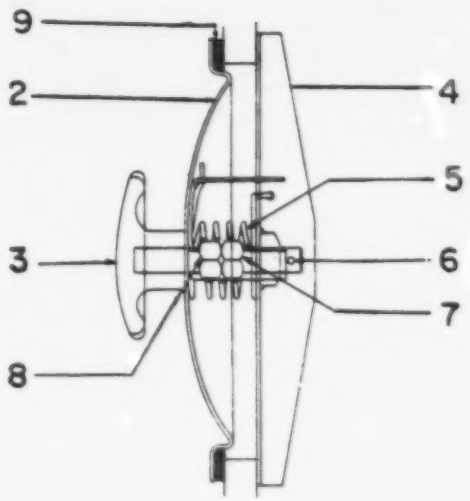


Ref. No.	Part No.	No. Req.	Description
1	24200421	1	Deep bowl piston and cap assy. 12.5:1 ratio
	24200422	1	Deep bowl piston body
	2421085	1	Washer
	2421094	1	Deep bowl cap
	2152788-1	2	Snap ring, piston pin retaining
	2421081	1	Washer
	21514978	3	Washer
	2152503	1	Nut
	24200512-1	1	Piston ring set (locomotive application, see Index)
2,3	24210232-1	2	Compression piston ring
4	24210233	1	Compression piston ring (taper face)
5,6	24210210	2	Scraper piston ring
	24200517	1	Piston ring set (Marine application, see Index)
2	24210240	1	Conformable scraper piston ring
3,4	2421029-1	2	Compression piston ring (taper face)
5	24210223	1	Conformable scraper piston ring
6	24210210	1	Scraper piston ring
7	2420021-2	1	Piston Pin with Sleeve
8	2421071		Sleeve
9	2170017-1	1	Main connecting rod assy., standard (see Index to determine requirements)
9	2170018	1	Main connecting rod assy., ABS inspected (see Index to determine requirements)
9	2170019	1	Main connecting rod assy., Lloyds inspected (see Index to determine requirements)
10	21511034	1	Dowel - cap to short rod
11	21511041	1	Dowel - cap to long rod
12	2171016-1	1	Bushing - piston pin end
13	2171053	4	Bolt, connecting rod to cap
14	2171052	4	Bolt, connecting rod to cap (with cotter pin hole), use with ABS 2170018
15	2151022	4	Nut, connecting rod bolt (unslotted)
16	2151021	4	Nut, connecting rod bolt (slotted), use with ABS 2170018
	2151401	4	Cotter pin nut locking, use with ABS 2170018
17	21710226	1	Bearing shell in connecting rod

Ref. No.	Part No.	No. Req.	Description
18	21710228	1	Bearing shell in connecting rod cap
19	22110115	1	Cylinder liner (chrome plated)
	*22110120	1	Cylinder Liner (screen chrome)
	25010627	1	Gasket set, cylinder liner to cylinder block
20		1	Gasket, top (not furnished separately)
21		1	Gasket, center (not furnished separately)
22		1	Gasket, bottom (not furnished separately)

*Added or Changed Since Last Issue.

ENGINE BASE DOOR

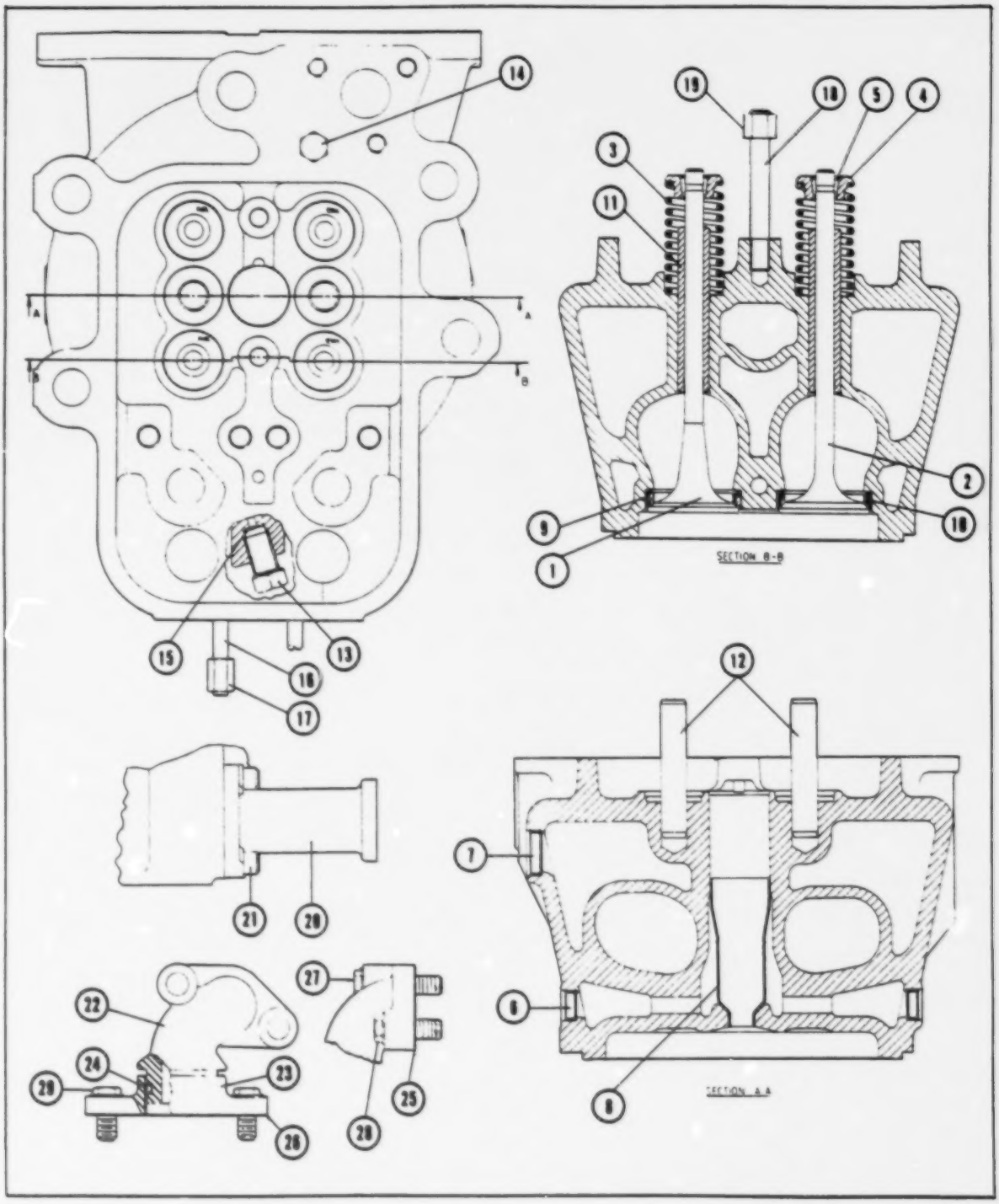


Ref. No.	Part No.	No. Req.	Description
1	2140013-3	1	Engine base door (assembly)
2	2141065	1	Door only
3	2141312	1	Knob with spindle
	21533819	1	Seal washer, spindle to cover
4	2141075	1	Locking bar
5	2461032	1	Locking spring
6	21510525	1	Spirol pin, spindle to bar, 3/16 x 1
7	2151691-1	1	Spindle nut, 5/8-11
8	21552226	1	Special nut, spindle to cover
9	2151123-3	1	Gasket, cover to base
	2155931-1	1 qt.	Cement, gasket to cover

Data Subject To Change Without Notice.

CYLINDER HEAD

WITH STANDARD AIR AND EXHAUST VALVES AND ROTOCOIL SPRING SEATS



Data subject to change without notice.

Ref. No.	Part No.	No. Req.	Description
	22200234	1	Cyl. head & valve assy.
1	22311211	2	Air valve
2	2231129	2	Exh. valve
3	2461086	4	Spring (air & exh. valve)
4	2231235	4	Spring seat (rotocoil)
5	2231152	8	Lock (spring seat)
	22200233	1	Cyl. head with inserts, less valves
6	2322452	7	Plug - expansion, 1"
7	2322453	4	Plug - expansion, 1-5/8"
8	2221092-2	1	Sleeve
9	22211821	2	Valve seat insert (air)
10	22211822	2	Valve seat insert (exh.)
11	22311310	4	Guide (air & exh. valve)
12	2241024-1	2	Guide (valve lever yoke)
13	2221081-2	1	Set screw, sq. hd.
14	54021-A	1	Plug
15	2151119	1	Gasket (copper)
16	21514279-3	2	Stud, 1/2-13 x 3-5/8 lg.
17	21516311	2	Nut, 1/2-13
18	2151429-5	2	Stud, 5/8-11 x 5-5/16 lg.
19	2151691-1	2	Nut, 5/8-11
20	2241295	2	Push rod housing
21	21549661	4	Capscrew, 3/8-16 x 1-1/4 lg.
	25000289	1	Water jumper kit
22	24010913	1	Elbow
23	24023133	1	Base
24	21542963	1	O'Ring
25	2152232-2	1	Gasket (at cyl. head)
26	21522311-1	1	Gasket (at cyl. block)
27	21513551-1	1	Capscrew, 1/2" NC x 2-3/4 lg.
28	21555891	1	Capscrew, 1/2" NC x 1-3/4 lg.
29	21513510-1	2	Capscrew, 1/2" NC x 1-1/4 lg., base to block
	2151313-1	4	Lockwasher, 1/2"

In process. Will be forwarded when available.

SAFETY DOOR

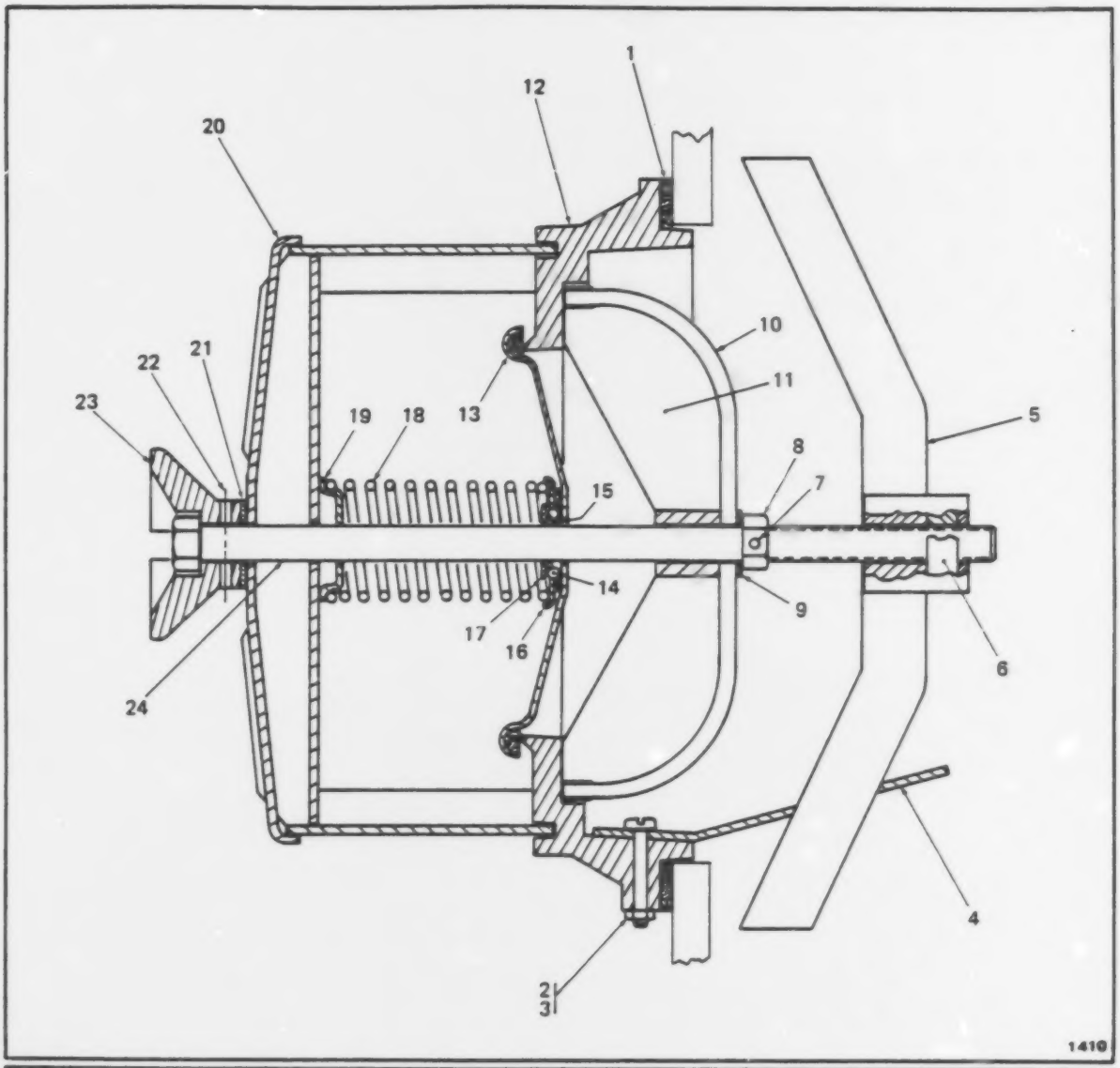


Fig. No.	Ref. No.	Part No.	No. Req.	Description
		2140083-1	1	Door, safety, assembly
	1	2151123-3	1	Gasket
		2155931-1	1	Cement, gasket (1 qt. can)
	2	8151081	3	Nut, clamp bar guide bolt
	3	8151016	3	Bolt, clamp bar guide
	4	21570414	1	Guide, clamp bar
	5	2141487	1	Bar, clamp
	6	21516929	1	Nut, clamp bar

Fig. No.	Ref. No.	Part No.	No. Req.	Description
	7	8151017	1	Set screw, 10 - 32 x 1/4 in.
	8	21516928	1	Locknut, spindle
	9	21521115	1	Washer, spindle
	10	2141154	1	Flame trap, wire gauze
	11	21570412	1	Spider, flame trap
	12	2157049	1	Carrier
	13	–	1	Plate, valve (part of service kit REF 25)
	14	–	1	Seal, spindle (part of service kit REF 25)
	15	–	1	Seal, spindle (part of service kit REF 25)
	16	21542992	1	Cap, spring, lower
	17	21542991	1	Seal, spindle retainer
	18	2461037	1	Spring, valve
	19	21542993	1	Cap, spring, upper
	20	2156057	1	Cover
	21	21521115	1	Washer, spindle
	22	2152904	1	Roll pin, knob
	23	21570413	1	Knob, spindle
	24	21570410	1	Spindle, valve
		21542996	1	Kit, service (comprising REFs. 13, 14, 15, allen wrench , 3/32 in. and instruction book)

PIPING - LUBRICATING & FUEL OIL

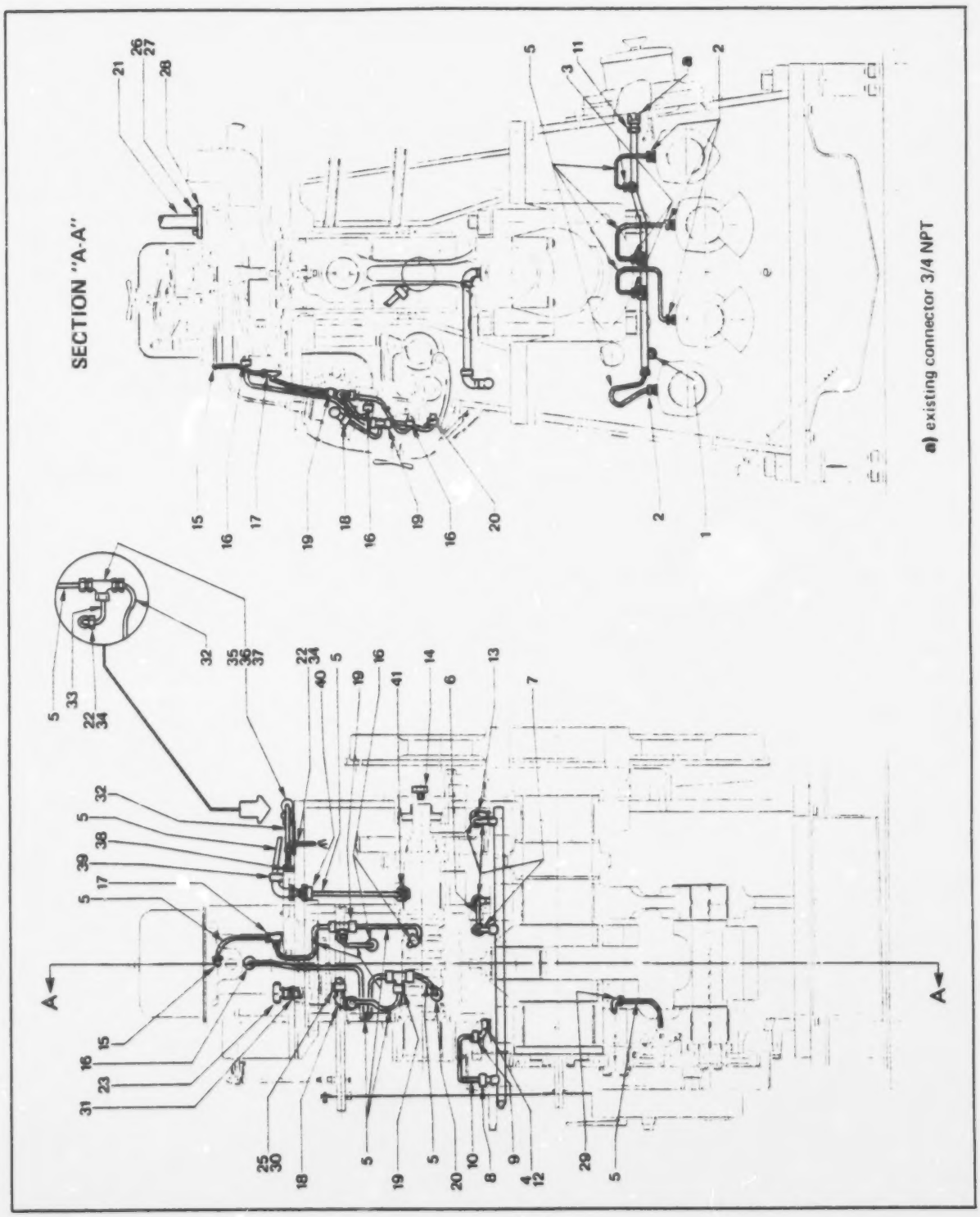
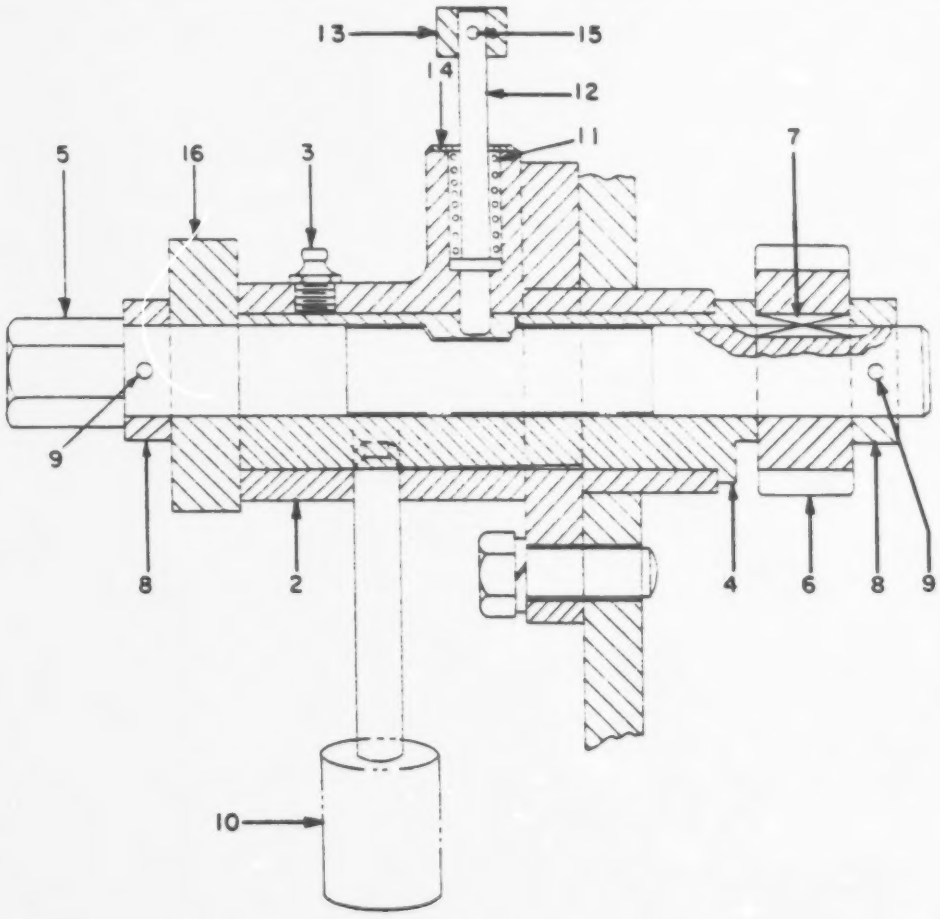


Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	84011315	1	Elbow, male, 6 OD tube x 1/8 NPT
	2	8401262	4	Connector, male, 3/8 OD tube x 1/4 NPT
	3	8401261	4	Connector, male, 3/8 OD tube x 1/8 NPT
	4	8401139	1	Elbow, male, 3/4 x 3/4 NPT
	5	84011214	1	ø Tube, 3/8 OD x 0.049 W x 56 in.
	6	84011215	1	Tube, 0.875 OD x 0.065 W x 22.81 in.
	7	84011310	4	Elbow, male, 7/8 OD tube x 3/4 NPT
	8	8401263	1	Connector, male, 7/8 OD tube x 3/4 NPT
	9	84011311	1	Elbow, female, 7/8 OD tube x 3/4 NPT
	10	84011216	1	Tube, 0.875 OD x 0.065 W x 25.25 in.
	11	8401265	1	Connector, male, 3/4 OD tube x 3/4 NPT
	12	84011811	1	Nipple, 3/4 NPT
	13	84011217	1	ø Tube, 7/8 OD x 0.065 W x 20 in.
	14	8401264	1	Connector, male, 3/8 OD tube x 3/8 NPT
	15	24023641	1	Elbow, male, 90° x 1/4 NPT
	16	24022834	2	Connector, male, 3/8 OD tube x 1/4 NPT
	17	2403269	1	Tee, male, 3/8 OD tube x 1/4 NPT
	18	24023664	2	Elbow, male, 90° x 1/8 NPT
	19	2403262	2	Tee, 3/8 OD tube x 9/16 - 18
	20	24023645	1	Elbow, male, 45° x 1/4 NPT
	21	8400101	1	Branch pipe assembly, cylinder head water outlet
	22	8401281	1	Nozzle, spray, camshaft gear
	23	8401058	1	Tee, male, 3/4 - 16
	24	8401266	1	Connector, male, 3/4 - 16 x 7/8 - 14
	25	8401267	1	Connector, male, G 1/8 x 1/8 NPT female
	26	21513511-1	3	Capscrew, 5/8 - 11 x 1-1/4 in. (zinc plated)
	27	21559352	AR	Sealant, Loctite (50cc bottle)
	28	81511016	AR	Sealant, Loctite (tube)
	29	84011312	1	Elbow, 3/8 OD tube x 1/8 NPT
	30	8401271	1	O-ring
	31	8401272	1	O-ring
	32	84011218	1	ø Tube, 1/2 OD x 0.032 W x 18 in.
	33	84011219	1	ø Tube, 1/4 OD x 0.035 W x 12 in.
	34	84011314	1	Elbow, male, 1/4 OD tube x 1/8 NPT
	35	2403263	1	Tee, 1/2 OD tube x 3/4 - 16
	36	2403363	1	Reducer, 1/2 OD tube x 3/8 NPT
	37	2403362	1	Reducer, 1/2 OD tube x 1/4 NPT
	38	8401268	1	Connector, male, 1/2 OD tube x 1/4 NPT
	39	84011313	1	Elbow, male, 3/8 OD tube x 9/16 - 18
	40	8401269	1	Connector, male, 3/8 OD tube x 9/16 - 18
	41	84012610	1	Connector, male, 3/8 OD tube x 1/8 NPT

ø Part number covers 1 foot length. Order quantity required.
AR As required.

BARRING DEVICE



REF. 1

Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	2290059	1	Barring device
	2	2291224	1	Housing
	3	2402421	1	Grease fitting
	4	2291255	1	Eccentric
	5	2291232	1	Shaft
	6	2351053	1	Gear
	7	21512712	1	Key
	8	2291261	2	Collar
	9	2291113	2	Pin
	10	2291331	1	Handle
		21533912	1	Dowel, taper, handle to eccentric, n° 00 x 1 in. long

Data subject to change without notice.

Fig. No.	Ref. No.	Part No.	No. Req.	Description
	11	24610921	1	Spring, locking pin
	12	2291093	1	Locking pin
	13	2291281	1	Knob, locking pin
	14	2151499	1	Washer
	15	2291115	1	Pin, spirol, knob to locking pin, 1/8 dia. x 3/4 in. long
	16	2291372	1	Cam
		23211313	2	Pin, spirol, cam to eccentric, 1/4 dia. x 1-1/4 in. long
		2362111	1	Microswitch
		8291025	1	Bracket, microswitch
		21555275	3	Capscrew, switch to bracket, 1/4 - 20 x 1 in.
		2151316-1	3	Lockwasher, 1/4 in.
		2151693-1	3	Nut, 1/4 - 20
		21513513-1	4	Capscrew, barring device to bracket, 1/2 - 13 x 1-1/2 in.
		2151313-1	4	Lockwasher, 1/2 in.
		2151353-1	2	Capscrew, bracket to main base, 3/8 - 16 x 3/4 in.

CRANKCASE EXHAUSTER

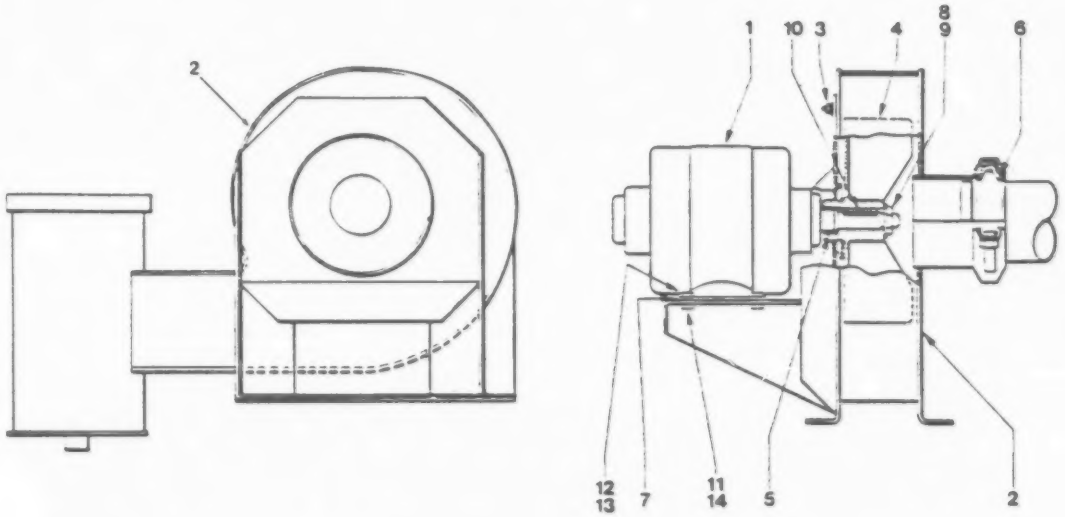
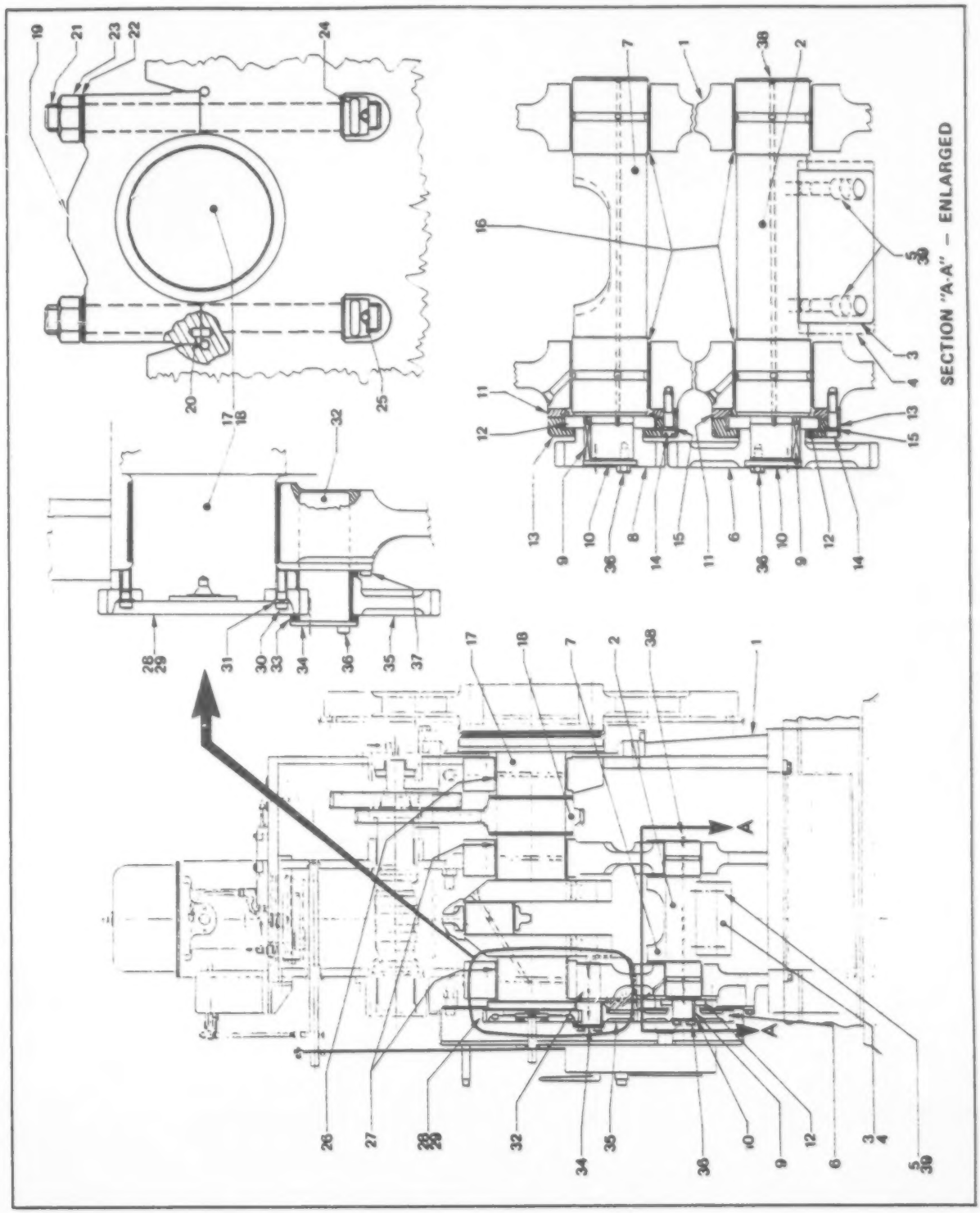


Fig. No.	Ref. No.	Part No.	No. Req.	Description
		24001421	1	Blower assembly, crankcase, with expansion chamber & motor
	1	2401775-1	1	Motor, crankcase exhauster
	2	24001417	1	Blower assembly, crankcase, less motor
	3	2151692-1	8	Nut, hexagon, 3/8 - 16
	3	2151312-1	8	Lockwasher, plain, 3/8 in.
	3	2151491-1	8	Washer, plain, 3/8 in.
	4	2401753	1	Wheel, blower
	5	24015317	1	Spacer, blower wheel
	6	16391385	1	Gasket, coupling, blower to elbow
	7	8151072	2	Shim, steel
	7	8151071	2	Shim, laminated brass
	8	2153832	1	Locknut, special, wheel retaining
	9	2152113	1	Lockwasher, special
	10	2151277	1	Key, flat, 3/16 x 3/16 x 3/4 in.
	11	21513524-1	4	Bolt, hexagon, 5/16 - 18 x 1 in., motor to blower
	12	2151698-1	4	Nut, hexagon, 5/16 - 18
	13	2151314-1	4	Lockwasher, spring, 5/16 in.
	14	2151499-1	4	Washer, plain, 5/16 in.

Data subject to change without notice.

ENGINE BASE

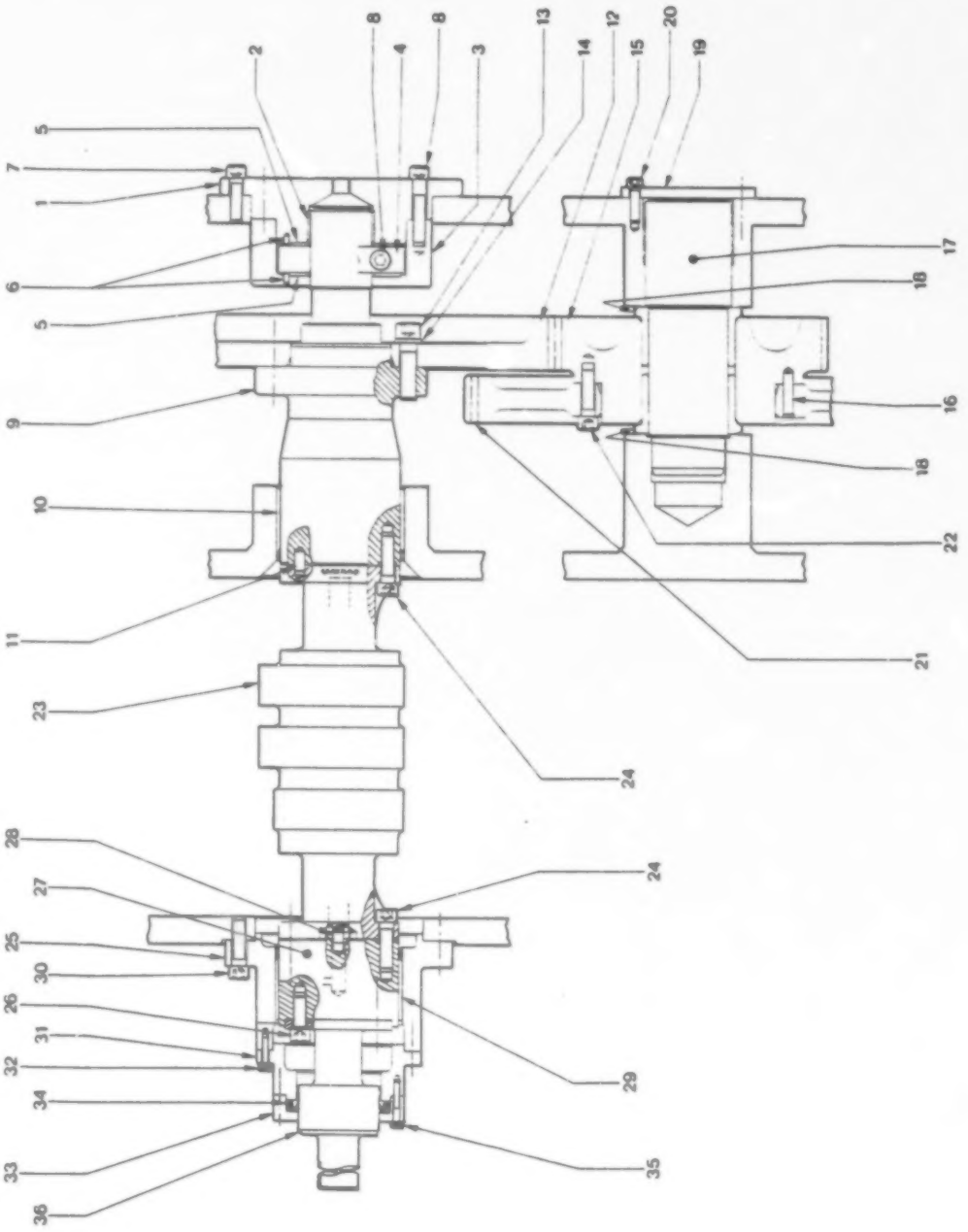


Data subject to change without notice.

Fig. No.	Ref. No.	Part No.	No. Required		Description
	1	8140012	1	–	Base, engine (1/251)
	1	8140011	–	1	Base, engine (1B2400)
	2	8191001	2	2	Balancer shaft, primary
	3	8191032	2	–	Weight, balancer shaft, primary
	4	8191031	–	2	Weight, balancer shaft, primary
	5	81510125	8	8	Capscrew, socket head, 3/4 - 10 x 3 in.
	6	8351014	2	2	Gear, balancer shaft, primary
	7	8191002	2	2	Balancer shaft, secondary
	8	8351015	2	2	Gear, balancer shaft, secondary
	9	8151103	4	4	Key, balancer shaft to gear, 5/8 x 1/2 in.
	10	8191061	4	4	Plate, thrust, balancer shaft
	11	8191675	4	4	Spacer, balancer shaft
	12	2191442	4	4	Washer, thrust, balancer shaft
	13	8191041	4	4	Retainer, thrust washer, balancer shaft
	14	21523538	12	12	Capscrew, socket head, 3/8 - 16 x 1-1/2 in.
	15	21513149	12	12	Lockwasher, 3/8 in.
	16	2141581	8	8	Bushing, balancer shaft
	17	8190024	1	–	Crankshaft with split gear (1/251)
	17	8190023	–	1	Crankshaft with split gear (1B2400)
		8191071	1	–	Crankshaft
		8191072	–	1	Crankshaft
	18	8351012	1	1	Gear, split, crankshaft
		81510126	4	4	Capscrew, 5/8 - 18NF - 3A x 4 in.
		21512777	1	1	Key, crankshaft split gear, 1 x 3/4 x 4-3/4 in.
		2151054	2	2	Dowel, crankshaft split gear, 1/2 x 1 in.
	19	8311021	3	3	Cap, bearing
	20	2151057	3	3	Dowel, bearing cap
	21	8151123	6	6	Stud bolt, bearing cap
	22	81510926	6	6	Washer, special, stud bolt
	23	81510814	6	6	Nut, 1-3/4 - 12 UN - 3B, stud bolt
	24	81510815	6	6	Nut, winged, stud bolt
	25	21514047	6	6	Pin, cotter, 7/16 x 3 in.
	26	21410365	1	1	Shell, thrust bearing
	27	21410166	2	2	Shell, main bearing
	28	8351016	1	1	Gear, crankshaft
	29	2151054	1	1	Dowel, crankshaft gear, 1/2 x 1 in.
	30	21555113	6	6	Capscrew, gear retaining, 1/2 - 13 x 1-3/4 in.
	31	21513146	6	6	Washer, 1/2 in.
	32	8191003	1	1	Idler shaft
	33	8191051	2	2	Bearing, idler shaft
	34	8191062	1	1	Plate, thrust, idler shaft
	35	8351013	1	1	Gear, idler shaft
	36	2152353	18	18	Capscrew, thrust plate retaining, 1/2 - 13 x 1 in.
	37	21549661	4	4	Capscrew, idler shaft retaining, 3/8 - 16 x 1-1/4 in.
	38	515592A	4	4	Plug, pipe, 1/8 in.
	39	21559341	AR	AR	Loctite, No. 271

AR As required.

CAMSHAFT AND DRIVE ASSEMBLY



Data subject to change without notice.

Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	8161051	1	Housing, camshaft bearing
	2	8161041	1	Bearing, camshaft housing
	3	8161052	1	Housing, thrust bearing
	4	8161061	1	Collar, thrust
	5	8161071	2	Washer, thrust
	6	8151141	4	Pin, taper
	7	81510129	6	Capscrew, special
	8	81510130	7	Capscrew, special
	9	81610347	1	Shaft, drive end
	10	2161332	1	Bearing, shaft, drive end
	11	21511088	1	Dowel, straight, 3/8 x 3/4 in.
	12	8351019	1	Gear, camshaft drive
	13	81510128	6	Capscrew, 5/8 - 18 x 2-1/4 in.
	14	81510925	6	Washer, 5/8 in.
	15	8351018	1	Gear, idler shaft
	16	21511071	1	Dowel, straight, 3/8 x 1 in.
	17	8351021	1	Shaft, camshaft idler
	18	8351041	2	Bearing, idler shaft
	19	8141027	1	Cover, idler shaft
	20	21523534	4	Capscrew, 3/8 - 16 x 1-1/4 in.
	21	8351017	1	Gear, camshaft idler drive
	22	21555113	6	Capscrew, 1/2 - 13 x 1-3/4 in.
	23	81610346	1	Camshaft section
	24	2155549	12	Capscrew, 1/2 - 20 x 1-3/4 in.
	25	8161053	1	Housing, free end
	26	21555411	3	Capscrew, 1/2 - 20 x 1-1/4 in.
		21559352	AR	Loctite (50 cc)
	27	8161042	1	Bearing, free end
	28	21511088	1	Pin, dowel, 3/8 x 3/4 in.
	29	2161332	1	Bearing, free end
	30	21555113	4	Capscrew, 1/2 - 13 x 1-3/4 in.
	31	8161054	1	Housing, encoder
	32	21523531	6	Capscrew, 1/4 - 20 x 1 in.
	33	8161015	1	Cover, encoder
	34	8151069	1	Seal, oil
	35	81510127	6	Capscrew, 1/4 - 20 x 1-1/2 in.
	36	8161081	1	Shaft, extension, encoder

AR As required.

VALVE LEVERS, SUPPORT AND CASINGS

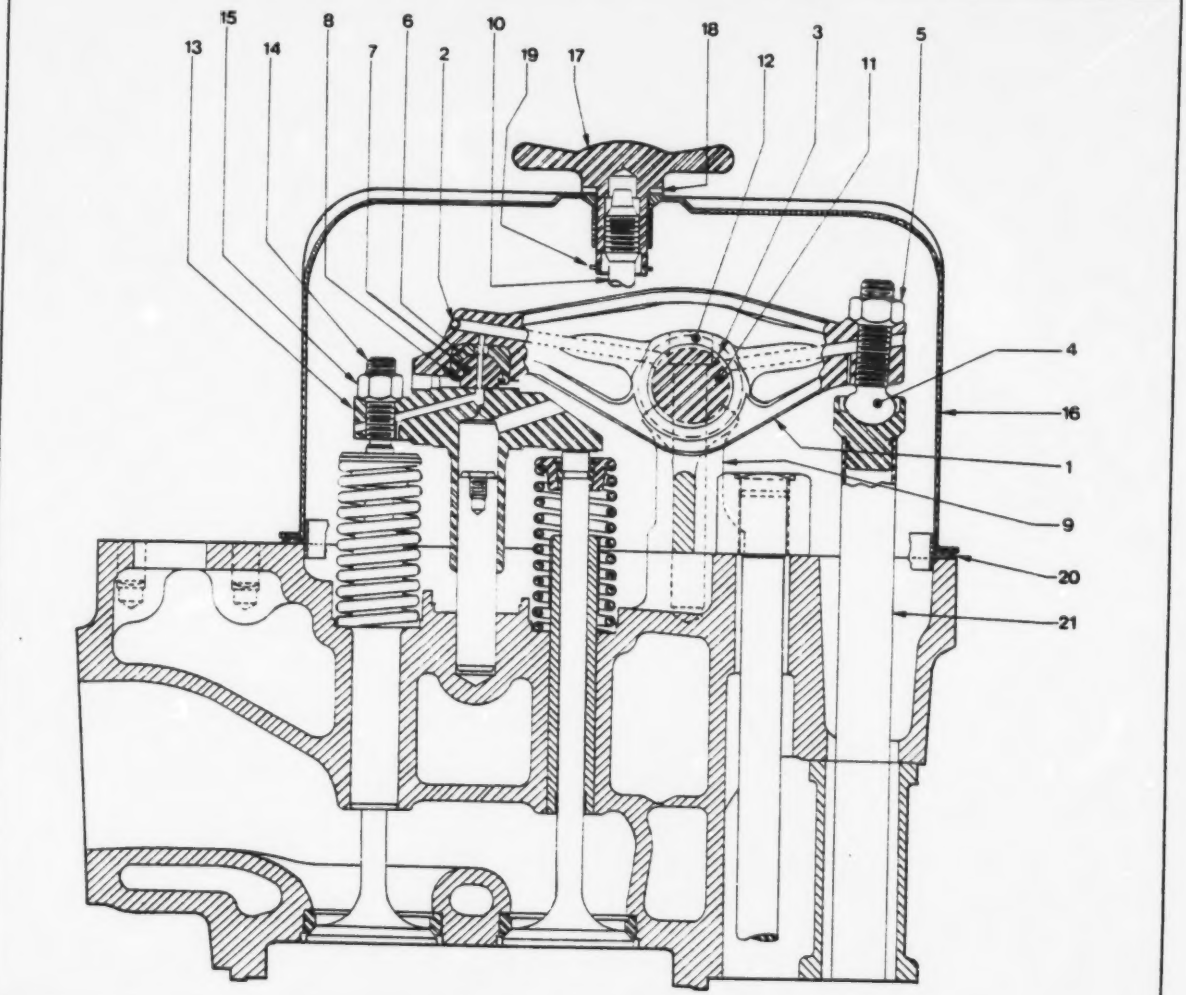


Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	2240211-1	2	Valve lever
	2	21556613	2	Plug, oil hole
	3	2153632	2	Bushing, in lever
	4	2241101	2	Adjusting screw, pushrod
	5	2153271	2	Nut, special
	6	2241261	2	Seat, valve lever
	7	2241271	2	Thrust ball
	8	2241281-1	2	Snap ring
	9	2241283	1	Support, valve lever shaft
	10	21518815	1	Stud, in support
	11	2241322-5	1	Shaft, valve lever
		16393717	1	Pipe plug, 1/8 in. IPS, hexagonal socket, in shaft

Data subject to change without notice.

Fig. No.	Ref. No.	Part No.	No. Req.	Description
	12	21523510	4	Capscrew, 3/4 - 10 x 5-1/2 in., socket head, shaft end support to cylinder head
	13	2231174-2	2	Yoke, air and exhaust valve
	14	2151921-1	2	Adjusting screw
	15	2241251-1	2	Nut, hexagonal, for adjusting screw
	16	2240054	2	Valve lever casing
	17	2322611-1	1	Handle nut
	18	2153385	1	Washer
	19	21527832	1	Ring, retaining
	20	21512011	1	Gasket, valve lever casing to cylinder head
		2155931	AR	Liquid cement, one quart can
	21	2240014-2	2	Pushrod, air and exhaust

AR As required.

OVERSPEED TRIP LINKAGE

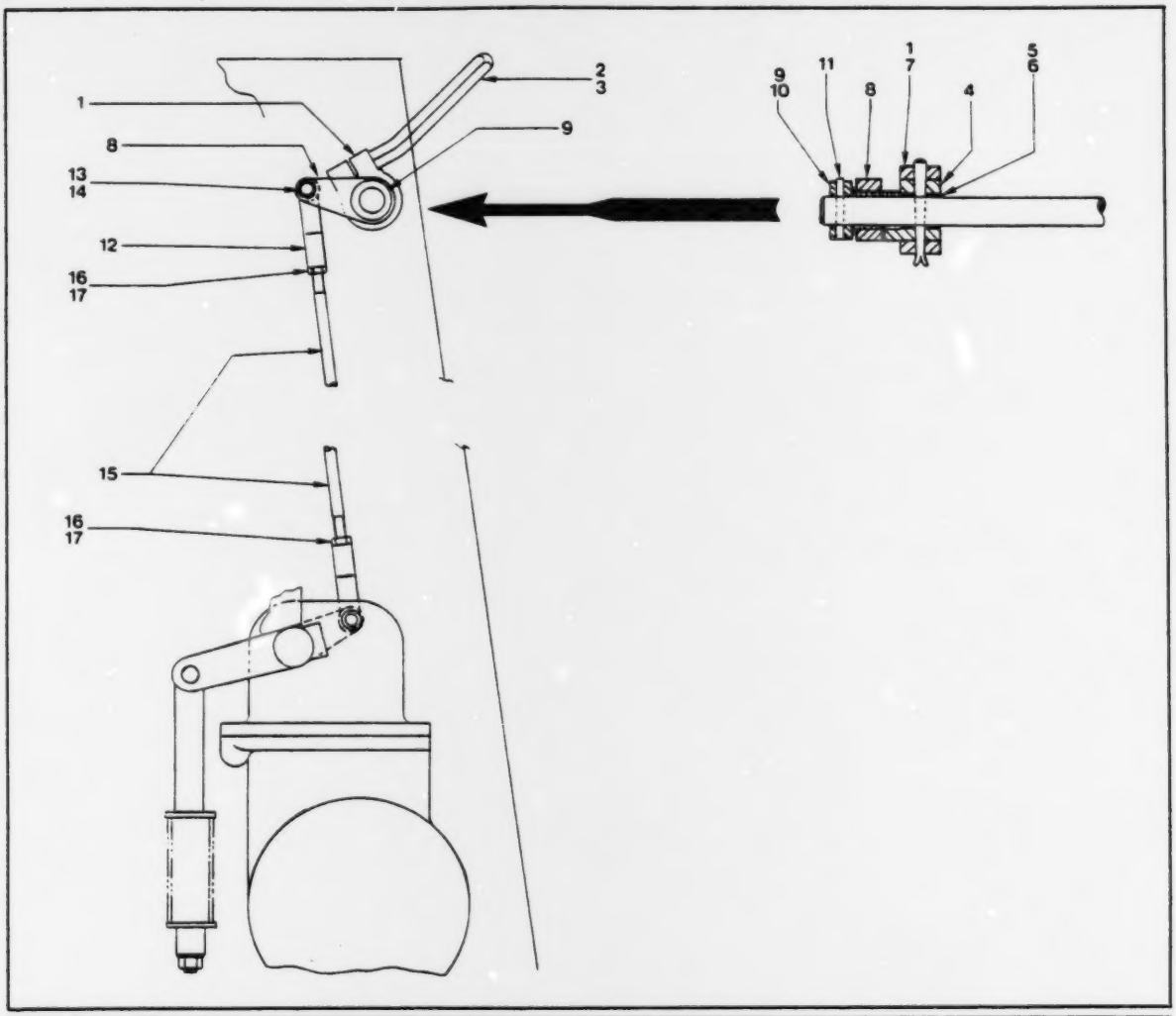


Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	8361116	1	Lever, handle retaining
	2	8361071	1	Handle, lever
	3	2151697-1	1	Nut, handle
	4	2361458	1	Collar, lever insert
	5	8361081	1	Sleeve, collar insert
	6	21520722	1	Setscrew, 1/4 - 20 x 1/4 in., sleeve retaining
	7	21528312	1	Pin, taper no 5 x 3 in., lever retaining
	8	8360051	1	Lever assembly
		8361091	1	Bushing
	9	8361101	1	Collar, lever assembly retaining
	10	2150722	1	Setscrew, 1/4 - 20 x 1/4 in., collar retaining
	11	2361115	1	Pin, spirol, 1/4 x 1-1/2 in., collar retaining

Data subject to change without notice.

Fig. No.	Ref. No.	Part No.	No. Req.	Description
	12	2321895	1	Yoke, pull rod
	13	23211320-1	1	Pin, clevis, yoke retaining
	14	2151401	1	Pin, cotter, 1/8 x 1-1/4 in.
	15	8361131	1	Rod, pull
	16	2151074	2	Nut, 1/2 - 20
	17	21559341	AR	Loctite, 50 cc bottle

AR As required.

CONTROL SHAFT LINKAGE AND FUEL OIL HEADER ASSEMBLY

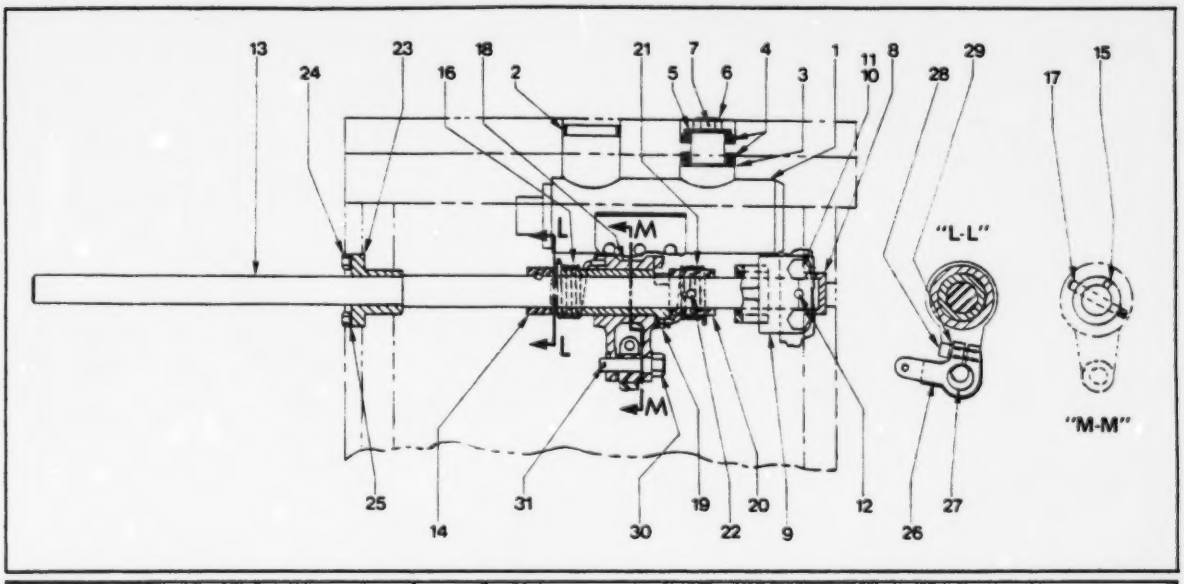


Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	84000316	1	Header assembly, fuel oil
	2	2151178	1	O-ring
	3	2402871	1	Retainer, grommet
	4	21534010	2	Grommet
	5	2151135	1	Washer
	6	2154965	1	Capscrew, 1/2 - 13 x 1-1/4 in.
	7	2157002	AR	Lockwire, stainless steel
	8	8361141	1	Bearing
	9	2321073-1	1	Bracket
		2152723	1	Bushing
	10	21555893	2	Capscrew, 3/8 - 16 x 1 in.
	11	21514920	2	Washer, 3/8 in.
	12	23211313	1	Pin, spirol, 1/4 x 1-1/4 in.
	13	8361151	1	Shaft, control
	14	2321861	1	Dog
	15	21520722	1	Screw, socket set, 1/4 - 20 x 1/4 in.
	16	24610911	1	Spring
	17	21528322	1	Pin, tapered, slotted, 2 in.
	18	2321805-1	1	Lever, spring
	19	2322355	1	Sleeve, control shaft
	20	2322552	1	Retainer
	21	24610911	1	Spring
	22	23211313	1	Pin, spirol, 1/4 x 1-1/4 in.
	23	8361082	1	Sleeve
	24	21549683	4	Capscrew, 1/4 - 20 x 3/4 in.
	25	2151496-1	4	Washer, 1/4 in.

AR As required.

Data subject to change without notice.

Fig. No.	Ref. No.	Part No.	No. Req.	Description
	26	23210244	1	Lever, fuel pump control
	27	2322622	1	Eccentric
	28	21523511	1	Capscrew, 5/16 - 18 x 1 in.
	29	21513124	1	Lockwasher, 5/16 in.
	30	8321081	1	Pin
	31	2151402	1	Pin, cotter, 3/4 in.

GOVERNOR CONTROL LINKAGE

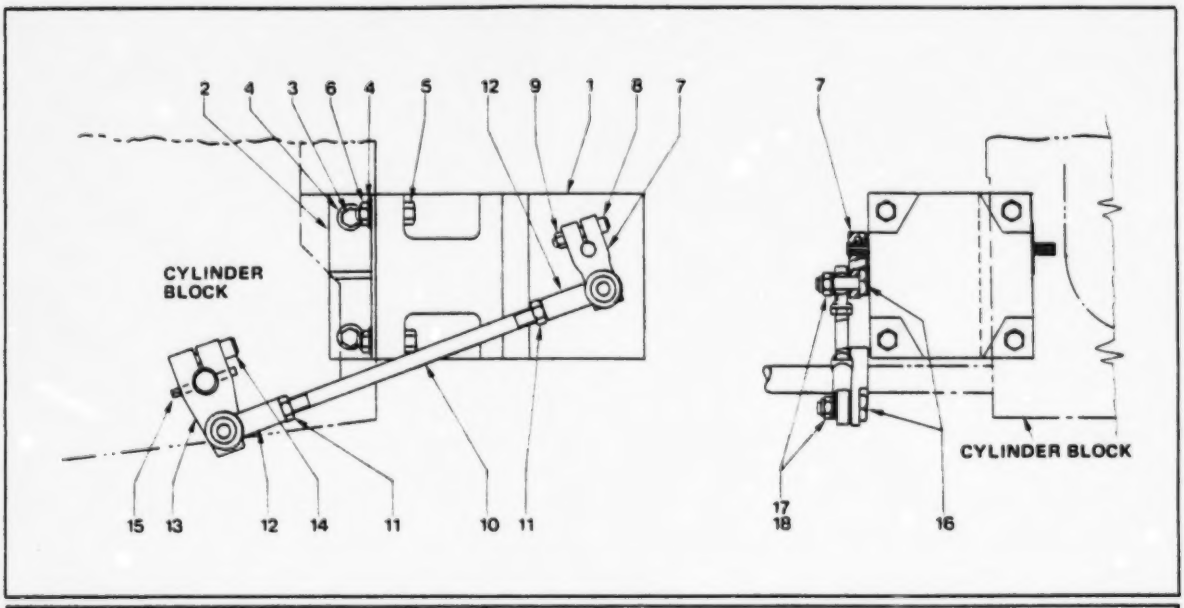


Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	83600913	1	Governor assembly
	2	8311031	1	Bracket, governor to cylinder block
	3	2151353-1	2	Capscrew, 3/8 - 16 x 3/4 in.
	4	2151491-1	4	Washer, 3/8 in.
	5	21556097	4	Capscrew, 3/8 - 16 x 1-3/4 in.
	6	2151692-1	2	Nut, 3/8 - 16
	7	8361117	1	Lever
	8	81510131	1	Capscrew, metric, M8 x 1.25 x 50 lg.
	9	81510816	1	Nut, metric, M8 x 1.25
	10	8361132	1	Rod, link
	11	2151074	2	Nut, jam, 1/2 - 20
	12	8361133	2	Rod end with bearing
	13	8361118	1	Lever
	14	81510132	1	Capscrew, metric, M10 x 1.5 x 45 lg.
	15	21528322	1	Dowel, 1/4 in.
	16	81510133	2	Bolt, square head, 1/2 - 13 x 1-3/4 in.
	17	2151495-1	2	Washer, 1/2 in.
	18	21513724	2	Nut, self-locking, 1/2 - 13

Data subject to change without notice.

OIL CATCHER

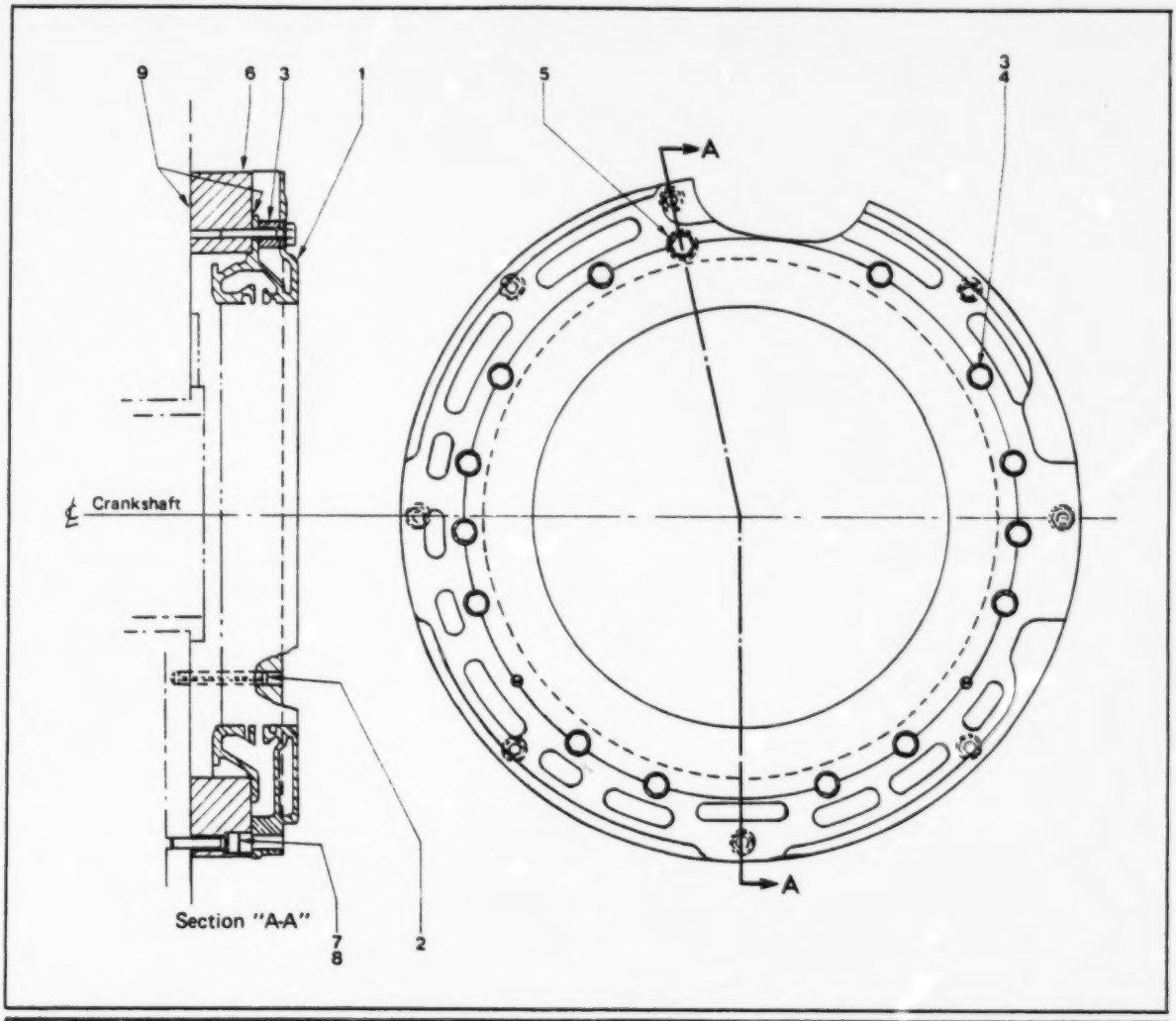


Fig. No.	Ref. No.	Part No.	No. Req.	Description
	1	8191731	1	Oil catcher
	2	8151142	2	Pin, spirol, 1/2 x 4 in.
	3	2154056	15	Capscrew, 1/2 - 13 x 2-1/2 in.
	4	81510927	15	Washer, 1/2 in.
	5	8191677	1	Spacer
	6	8191676	1	Spacer
	7	81510134	8	Capscrew, socket head, 1/2 - 13 x 2-1/4 in.
	8	21513120	8	Lockwasher, 1/2 in.
	9	21559343	AR	Silicone, 11 oz. cartridge

AR As required.

Data subject to change without notice.

OVERSPEED TRIP

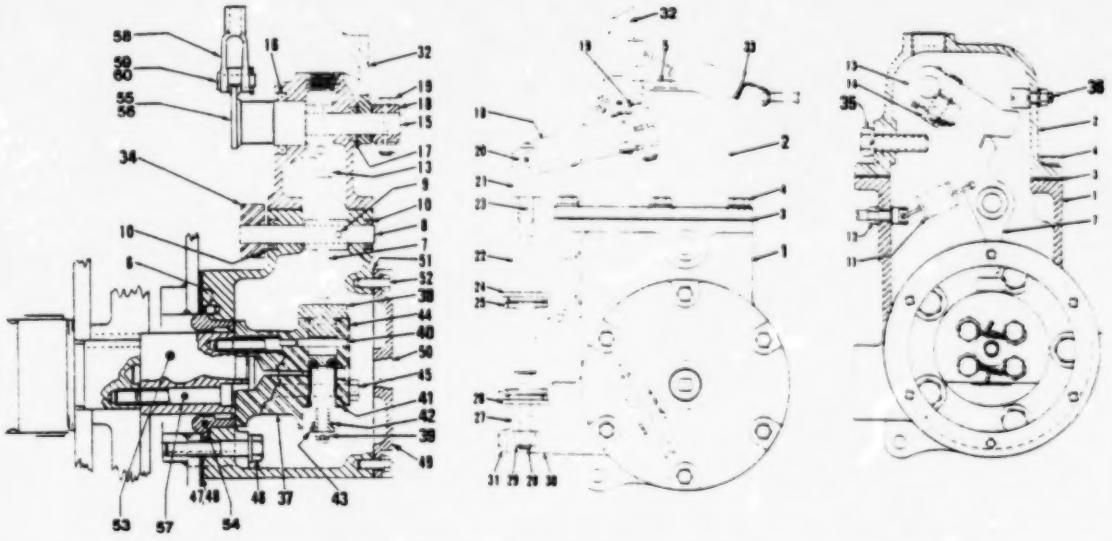


Fig. No.	Ref. No.	Part No.	No. Required		Description
		– – –	1	–	Overspeed trip (182400)
		– – –	–	1	Overspeed trip (1/251)
	1	23614214	1	1	Lower housing
	2	2361433	1	1	Upper housing
		2161132	1	1	Camshaft thrust bearing
		515580A	1	1	Pipe plug, upper housing, 1 IPS
	3	21511888	1	1	Gasket, upper to lower housing
	4	21513510-1	3	3	Capscrew, upper to lower housing, 1/2 - 13 x 1-1/4 in.
	5	21560619	1	1	Capscrew, upper to lower housing, 1/2 - 13 x 6 in.
		2153084	2	2	Capscrew, special, upper to lower housing
		2151313-1	4	4	Lockwasher, 1/2 in.
		2151311-1	2	2	Lockwasher, 5/8 (special screw)
	6	21511087	1	1	Dowel, thrust bearing to lower housing, 3/8 dia. x 5/8 in.
	7	2361249	1	1	Trip lever
	8	23613123	1	1	Trip lever shaft
	9	2152206	1	1	Taper dowel, special, lever to shaft
	10	2361343-1	2	2	Oil seal, trip lever shaft
	11	24610913	1	1	Trip lever spring
	12	2153085	1	1	Screw, special, trip lever spring
		2151692-1	1	1	Nut, 3/8 - 16
		2151312-1	1	1	Lockwasher, 3/8 in.
		21511116	1	1	Copper gasket
	13	2361444	1	1	Lever arm
	14	5151242	1	1	Capscrew, 1/2 - 13 x 1-3/4 in.
		2157002	1	1	·ø Lockwire, 0.080 x 24 in.

ø Order quantity required, will ship to nearest stock length.

Fig. No.	Ref. No.	Part No.	No. Required		Description
	15	23613124	1	1	Lever arm shaft
	16	2361344-1	1	1	Oil seal, lever arm shaft, inner
	17	23613411	1	1	Oil seal, lever shaft, outer
	18	8361114	1	1	Trip lever
		2152206	1	1	Dowel, special, lever to shaft
	19	21513512-1	1	1	Capscrew, lever to shaft, 1/2 - 13 x 2 in.
		2151697-1	1	1	Nut, 1/2 - 13
		2151313-1	1	1	Lockwasher, 1/2 in.
	20	23211320-1	1	1	Pin, special, trip lever to link
		2157054	1	1	Cotter pin, 3/32 x 3/4 in., stainless steel
	21	2361534	1	1	Link, trip mechanism
	22	2361168	1	1	Sleeve, trip mechanism
	23	21511065	1	1	Dowel, link to sleeve, 1/8 x 1-1/4 in.
	24	23613713	1	1	Upper spring retainer
	25	24610943	1	1	Trip spring
	26	23613712	1	1	Lower spring retainer
	27	2362371	1	1	Trunion
		21515710	1	1	Nut, 1/2 - 13
		21513151	1	1	Washer, 1/2 in.
		21514094	1	1	Cotter pin, 1/8 x 1 in., stainless steel
	28	23615619	1	1	Guide rod
	29	2151697-1	1	1	Hexagonal nut, 1/2 - 13
		2151313-1	1	1	Lockwasher, 1/2 in.
	30	2362352	1	1	Block, trip mechanism to lower housing
	31	21556338	2	2	Capscrew, block to housing, 1/2 - 13 x 2-1/2 in.
		2151313-1	2	2	Lockwasher, 1/2 in.
	32	8361115	1	1	Reset lever
	33	2461171-1	1	1	Spring, reset lever to turbo support
	34	23612411	1	1	Lever stop
		21513512-1	1	1	Capscrew, special, lever to shaft, 1/2 - 13 x 2 in.
		2151697-1	1	1	Nut, 1/2 - 13
		2151313-1	1	1	Lockwasher, 1/2 in.
		2152206	1	1	Dowel, taper, lever to shaft
	35	81510123	1	1	Capscrew, lever stop, 5/8 - 11 x 2-1/4 in.
		2151311-1	1	1	Lockwasher, 5/8 in.
	36	2153083	1	1	Screw, special, trip lever stop
		2151692-1	1	1	Nut, 3/8 - 16
		2151312-1	2	2	Lockwasher, 3/8 in.
		2151402	1	1	Cotter pin, 3/32 x 3/4 in., stainless steel
	37	8361013	1	1	Carrier
	38	8361014	1	1	Plunger
	39	21519117	1	1	Locknut, retainer to plunger, 3/8 - 24
	40	21511051	1	1	Dowel, plunger to carrier, 5/16 x 2 in.
	41	2361721-1	1	1	Spring seat
	42	8361015	1	1	Spring
	43	8361016	1	1	Retainer, spring
	44	2361411	1	1	Lockplate
	45	21549612	4	4	Capscrew, lockplate and carrier to camshaft, 1/2 - 13 x 5-1/2 in.
		2157002	1	1	ø Lockwire, 0.080 x 24 in.

ø Order quantity required, will ship to nearest stock length.

Fig. No.	Ref. No.	Part No.	No. Required		Description
	46	21513588-1	5	5	Capscrew, lower housing to block, 5/8 - 11 x 3 in.
		2151311-1	5	5	Lockwasher, 5/8 in.
		21510523	1	1	Spirol pin, housing to block, 1/2 x 1-3/4 in.
	47	23610110-1	AR	AR	Shim, housing to cylinder block, 0.064 thick
		23610111-1	AR	AR	Shim, housing to cylinder block, 0.0319 thick
		23610112-1	AR	AR	Shim, housing to cylinder block, 0.0159 thick
		23610113-1	AR	AR	Shim, housing to cylinder block, 0.0056 thick
	48	21522637-2	2	2	Gasket, shim to cylinder block
	49	2361134-1	1	1	Cover, lower housing
	50	515580A	1	1	Pipe plug, 1 IPS
	51	2152269	1	1	Gasket, cover to housing
	52	21555893	6	6	Capscrew, cover to housing, 3/8 - 16 x 1 in.
		2151312-1	6	6	Lockwasher, 3/8 in.
	53	8361061	1	1	Adapter
	54	2161132	1	1	Bearing, thrust
	55	8361112	1	–	Lever
	56	8361113	–	1	Lever
	57	81510124	2	2	Capscrew, adapter to balance shaft, 1/2 - 13 x 4 in.
	58	2321895	1	1	Yoke
	59	23211320-1	1	1	Clevis pin
	60	2151401	1	1	Cotter pin, 1/8 x 1 in.

ø Order quantity required, will ship to nearest stock length.
AR As required.

APPENDIX B LOE ENGINE DRAWINGS

Figure B.1 Single-cylinder engine 1-251 basic (drawing R94-014943)

Figure B.2 Single-cylinder engine 1-251 LOE (drawings R94-014979)

Figure B.3 Camshaft and drive assembly (drawing R94-016948)

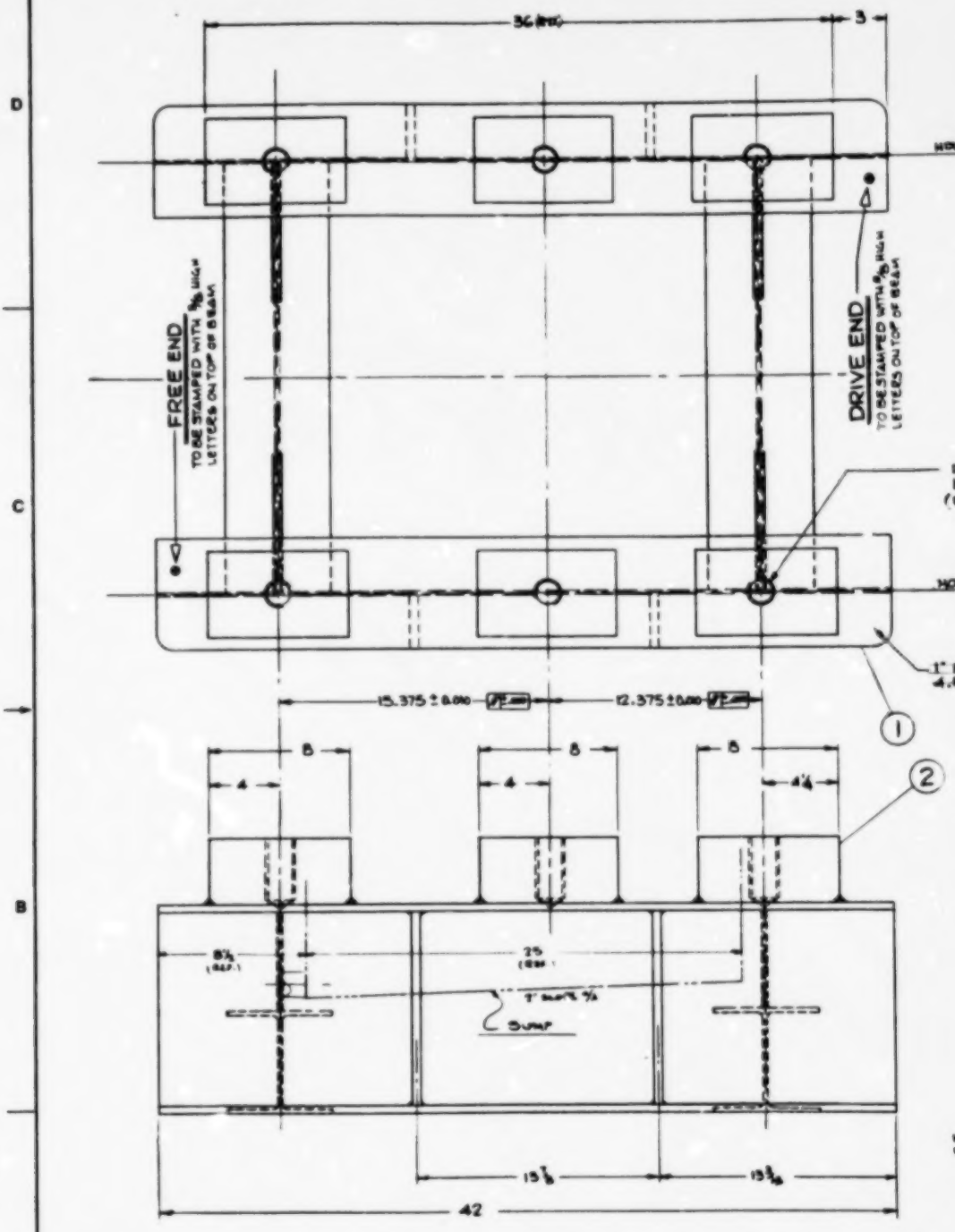
Figure B.4 Lube oil headers (drawing R94-040925)

Fibure B.5 Crankshaft assembly (drawing R94-019932)

Figure B.6 Main base (crankcase) assembly (drawings R94-019933)

Figure B.7 LOE engine 4 circuits oil flow diagram (drawing R94-058903)

Figure B.8 Lube oil system; test cell #5 (drawings R94-030910)


36
3
FREE END
TO BE STAMPED WITH 3/8 HIGH LETTERS ON TOP OF BEAM
DRIVE END
TO BE STAMPED WITH 3/8 HIGH LETTERS ON TOP OF BEAM
15.375 ± 0.000
12.375 ± 0.000
1" RAD. 4 PLACES
8
4
4 1/4
25
Sump
15 7/8
42

	1		BEAM	A. 36	WF - 12 @ 31# x 42 LG.		2	
	2		PAD	"	4 THK x 5 x 8		6	
	3		GUSSET	"	5/16 THK x 5 x 11 LG.		4	
	4		CAPSCREW HEX HD	GRADE 5 MIN	1 1/2 - 12 UNF - 5B x 7 1/2 LG (4" MIN. THD)		6	
	5		PLAIN WASHER	STL	1 1/2 DIA.		6	
	6		CROSS BEAM	A. 36	W-F - 6 x 6 @ 15.5# x 48 1/2 LG		2	
	7		GUSSET	"	5/16 THK x 5 5/16 x 8 LG		4	

HOLES TO BE IN LINE WITHIN ± 0.005

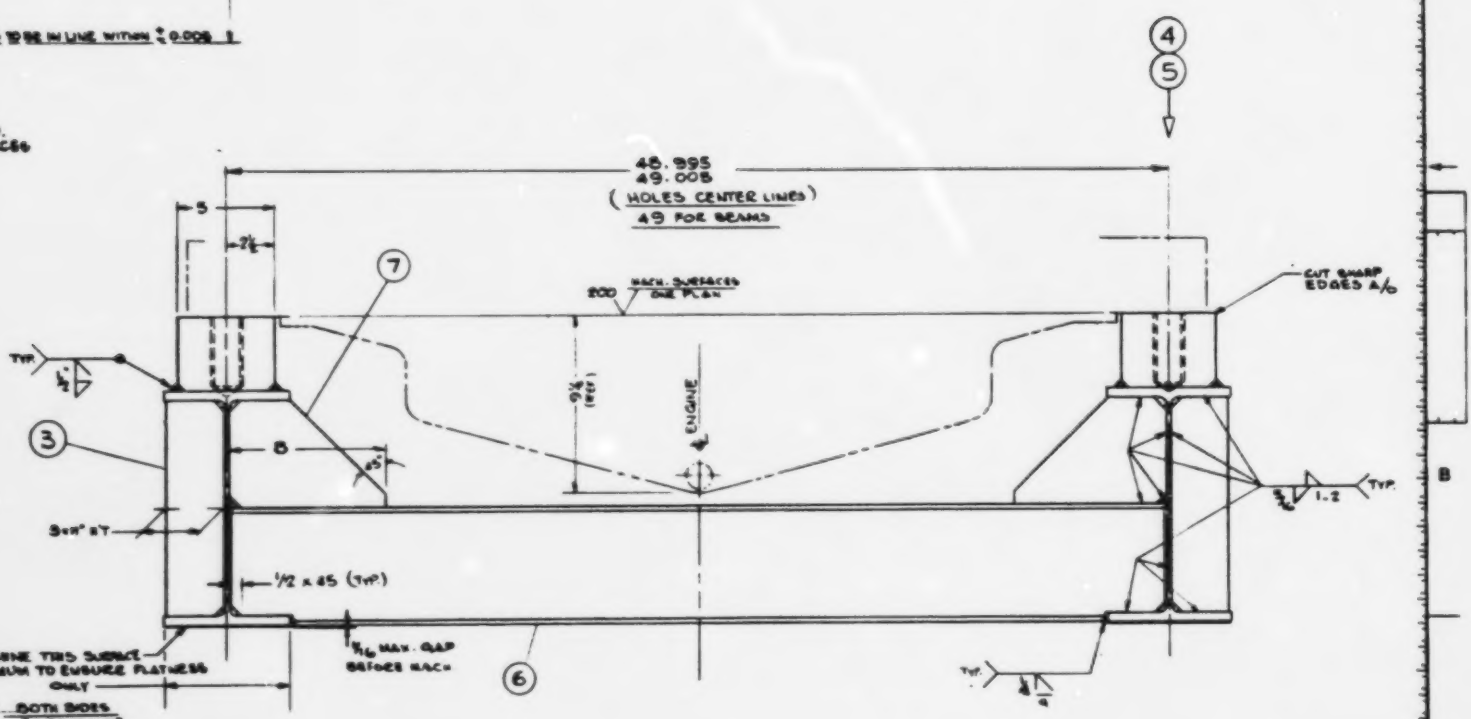
± .005

- DRILL & TAP 6 HOLES 1 1/2 - 12 UNF - 3A (DRILL TO WEB ONLY)

HOLES TO BE IN LINE WITHIN ± 0.005

APPROX. FINAL W'T = 680#
BOLTS EXCLD.

1" RAD. 4 PLACES



			—	FOR COTATION	—			
			—	ISSUED FOR FABRICATION	—			
			—	TOLERANCES + DIM'S, # BILL OF MAT'L REVISED ADD - ITEM 6 & 7	—			

PROJECTION

TOLÉRANCE ET ÉTAT DE SURFACE SAUF INDICATION CONTRAIRE

METRIQUE

IMPERIAL

FRAC (MACH.) ± 1/32

DÉCIMAL ± .005

FRAC (BRUT) ± 1/16

ANGLES ± 1/2° CHAMFREIN ± 1/2°

BAVURES 1.00" / 0.4mm MAX.

FINI DE SURFACE 1.25 mu in / 32

PLANT ENG'G REF. N° A1-8808

Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal, Quebec, Canada

ENGINE SKID
B.2400 & 251 SINGLE CYL. ENGINE
ENGINE R&D CENTER BLDG. #67 CELL #465

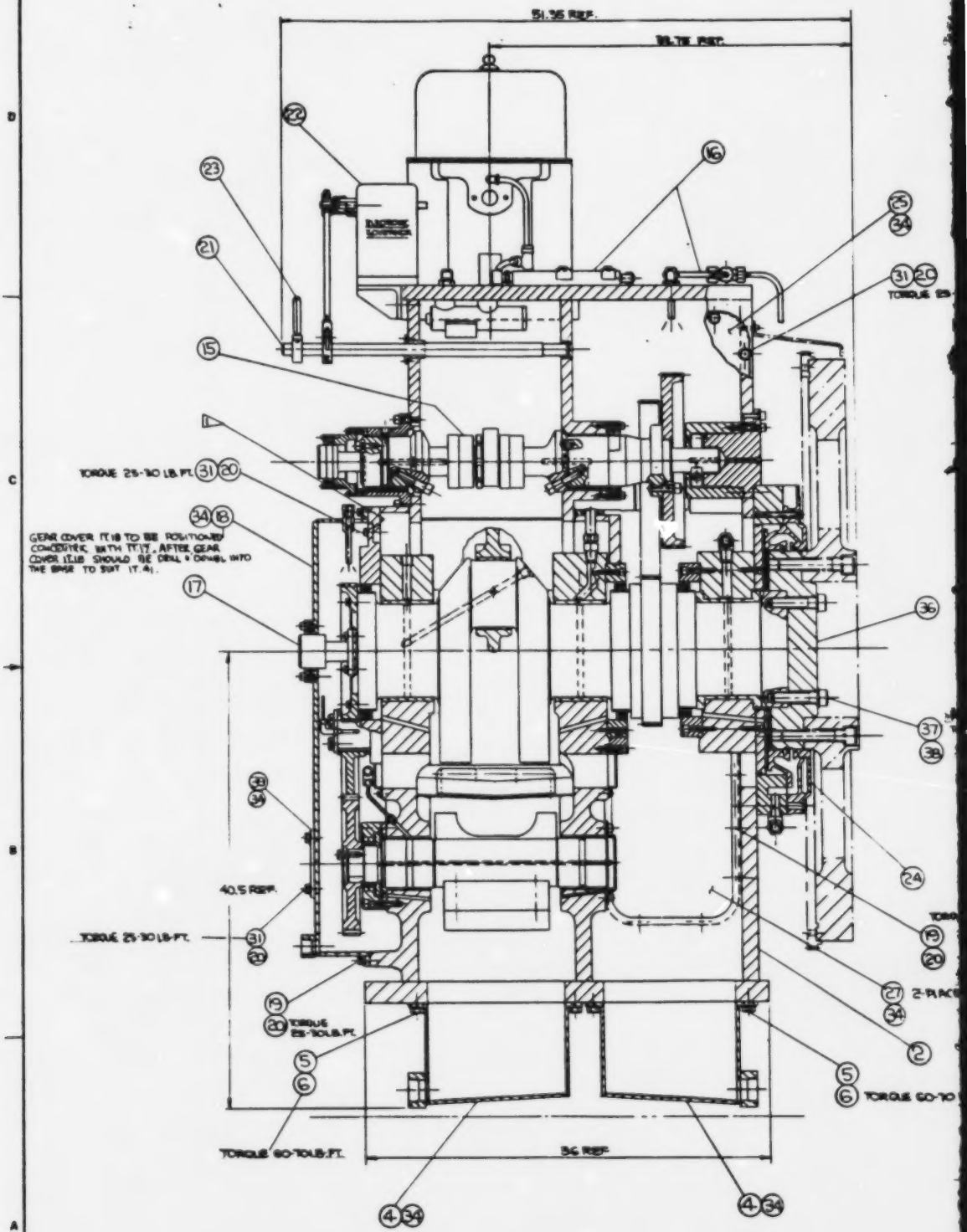
A1

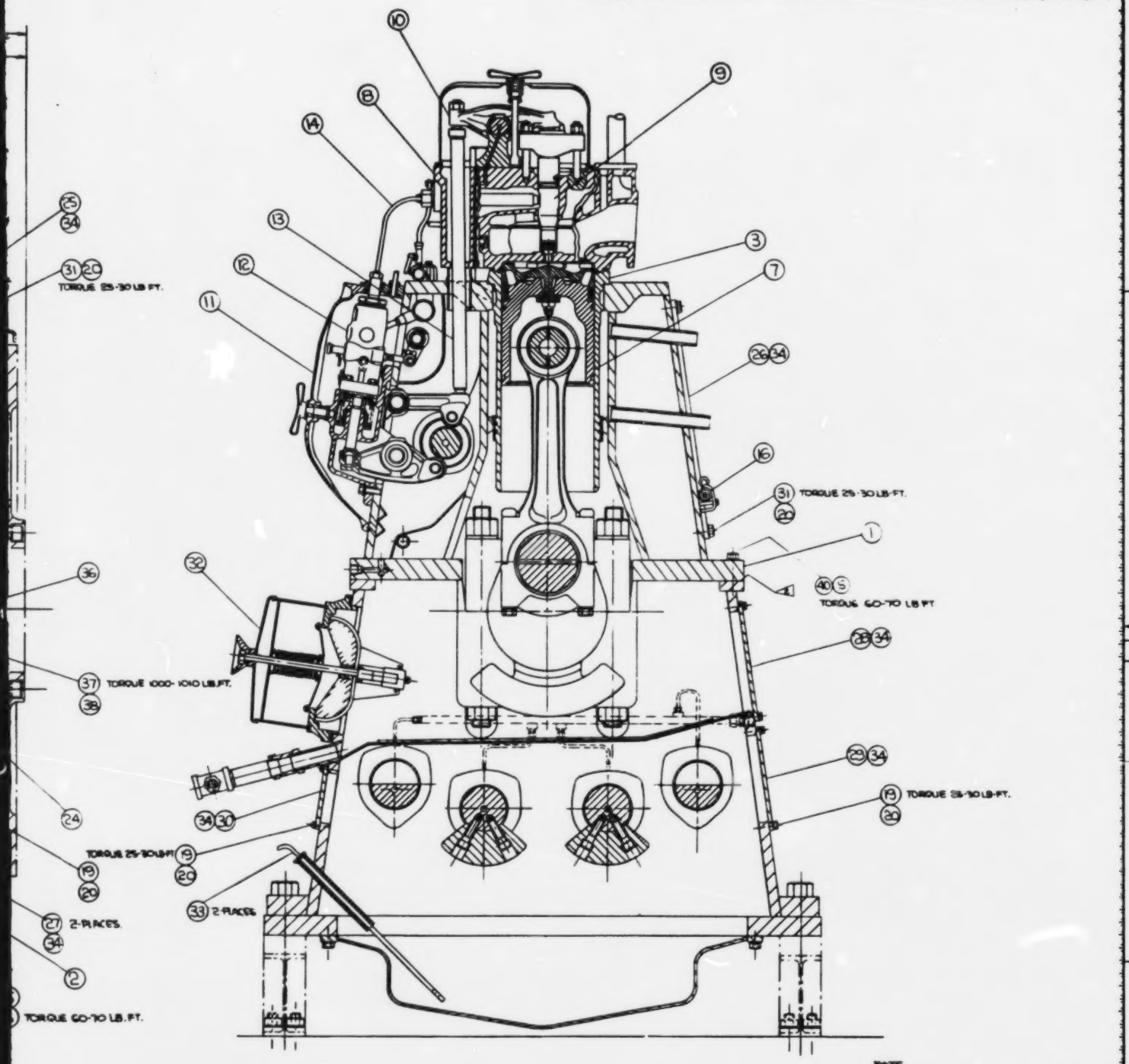
484200

1/1

R94.014943

FIGURE B.1


51.35 REF.
TORQUE 25-30 LB.FT.
GEAR COVER IT.18 TO BE POSITIONED CONCENTRIC WITH IT.17. AFTER GEAR COVER IT.18 SHOULD BE DRILL & DOWEL INTO THE BASE TO SUIT IT.41.
40.5 REF.
TORQUE 60-70 LB.FT.
36 REF.

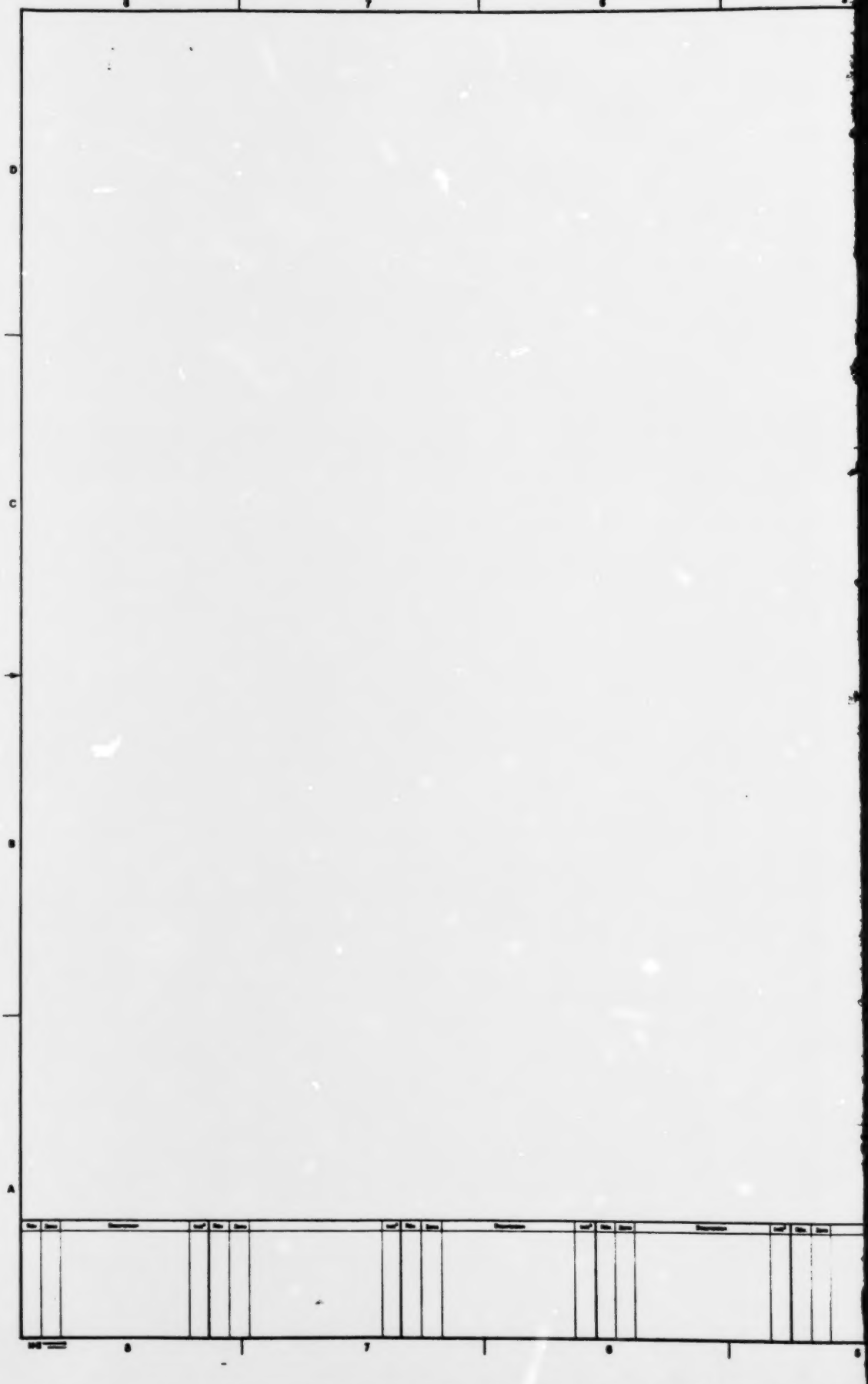


NOTE:

1. APPLY ITEM 34 ON THE COVER SURFACE.
2. APPLY SILICONE ITEM 34 BETWEEN BLOCK & BASE SURFACES BEFORE ASSEMBLED TOGETHER

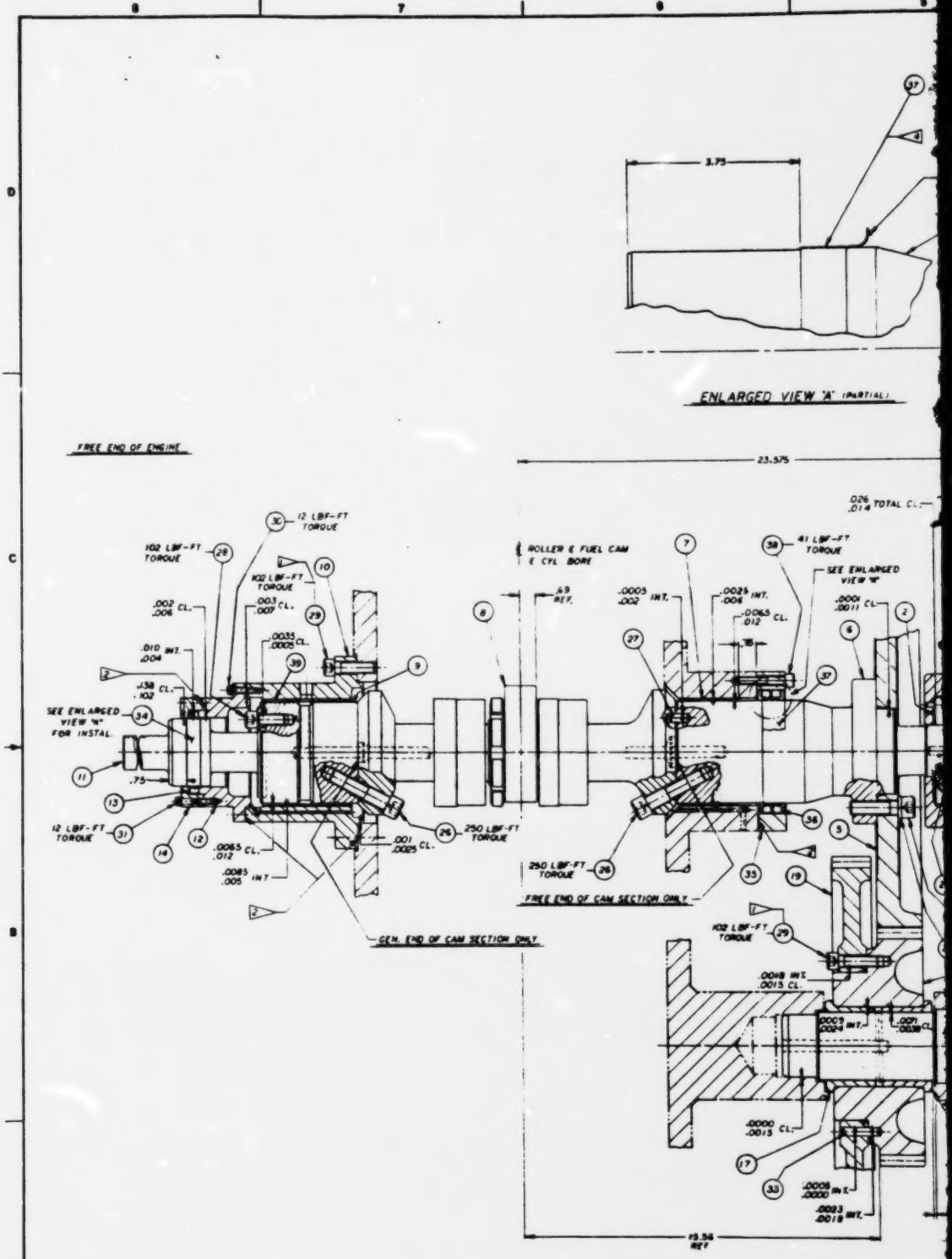
A	BCN 6-1975 IUCORP	SINGLE CYLINDER L.O.E ASS'Y	
		1-251 L.O.E AO	894-014979 A

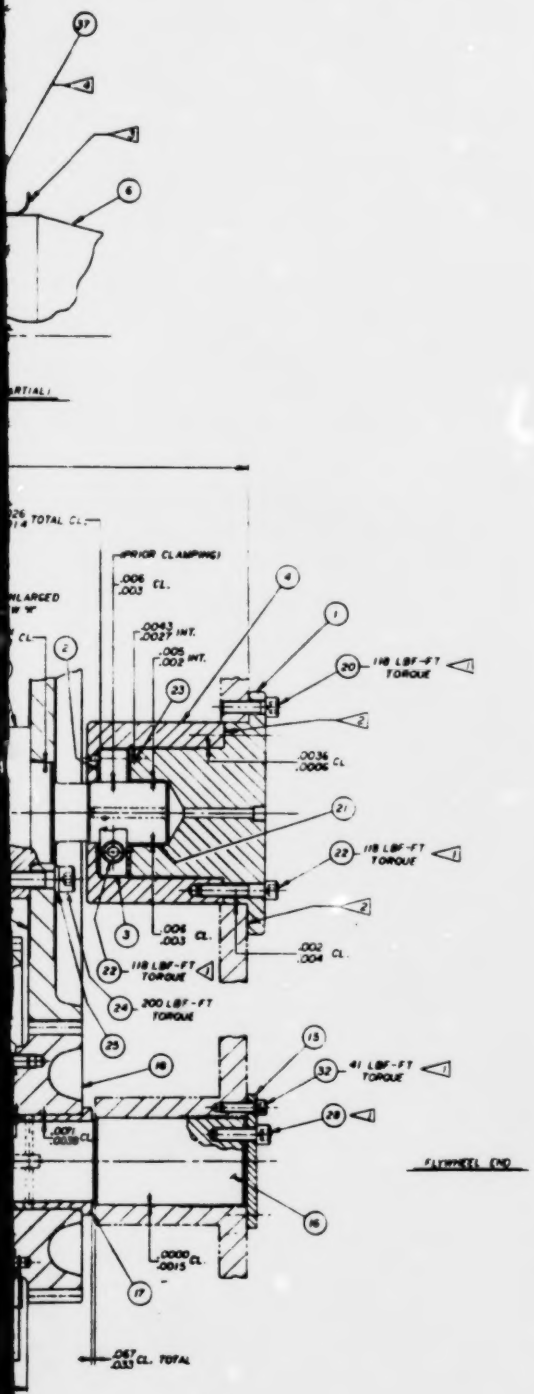
FIGURE B.2.1


8
7
6
5
D
C
B
A

1	R940149715001	BASE & BACK ASSY.				1	
2	R940199330001	BASE ASS'Y				1	
3	C210720270011	CYL. LINER DIRECT FIT				1	
4	R940149780001	SUMP ASS'Y.				2	
5	91P0838504016	LOCK WASHER		SIZE 1/2		42	
6	92P0116240400	SCREW CAP HEX.		1/2-13NC X 1 1/4" LG		32	
7	C420712500071	MAIN FRAME ASSEMBLY				1	
8	C220711640021	MAIN CYL HD. EFFECT				1	
9	C230741060031	NOZZLE HOLDER ASS				1	
10	C220711560031	CYL HD & VALVE ASS				1	
11	C320722710011	F.P SUP. & HOUSING ASS				1	
12	C320741080001	FUEL PUMP				1	
13	C240721440011	PUSH ROD ASS'Y				1	
14	C400362900001	FUEL INJ TUBE ASS				1	
15	R940169480011	CAMSHAFT GEAR ASS				1	
16	R940409250011	LUBE OIL HEADER ASS				1	
17	R940349110011	EXT. SHAFT ASS'Y.				1	
18	R940149810011	FREE END GEAR ASS				1	
19	92P0116230400	SCREW CAP. HEX.		3/8-16NC x 1 1/4" LG		70	
20	91P0838504096	LOCK WASHER		SIZE 3/8		122	
21	R940329010011	CONT. SHAFT LINK ASS				1	
22	R940365260011	GOV CONT LINK ASS'Y				1	
23	R940369460011	HANDLE ASS'Y				1	
24	R940199430011	OIL CATCHER ASS'Y				1	
25	R940169630011	COVER				1	
26	R940169320011	COVER				1	
27	R940149900011	COVER				2	
28	R940149910011	COVER				1	
29	R940149932011	COVER				1	
30	R940149930011	COVER				1	
31	92P0116230320	SCREW CAP HEX.		5/16-18NC x 1 LG		52	
32	C140774330011	EXPLOSION DOOR				1	
33	R940349070011	OIL GAUGE				2	
34	900581600147	SILICONE				A/R	
35							
36	R940199370011	END SPACER				1	
37	91P0150721280	SC HD CAPSCR.		1-8UNC x 4 LG		12	
38	91P0838504086	WASHER		SIZE 1		12	
39	R940149520011	COVER				4	
40	92P0116240800	SCREW CAP HEX.		1/2-13NC x 2 1/2 LG		10	
41	F2P0760110320	DOWEL		Ø1/2 x 1 LG		2	

| | | | | | | |


3.75
ENLARGED VIEW "A" (PARTIAL)
FREE END OF ENGINE
23.575
.026
.014 TOTAL CL.
12 LBF-FT TORQUE
102 LBF-FT TORQUE
102 LBF-FT TORQUE
ROLLER & FUEL CAM & CYL BORE
.69 REF.
41 LBF-FT TORQUE
SEE ENLARGED VIEW "B"
.002 .006 CL.
.003 .007 CL.
.0005 .002 INT.
.0025 .006 INT.
.0065 .012 CL.
.0001 .0011 CL.
.010 INT. .004
.0035 .0025 CL.
.138 .102 CL.
SEE ENLARGED VIEW "B" FOR INSTAL.
.75
12 LBF-FT TORQUE
.0065 .012 CL.
.0085 .005 INT.
.001 .0025 CL.
250 LBF-FT TORQUE
250 LBF-FT TORQUE
FREE END OF CAM SECTION ONLY
GEN. END OF CAM SECTION ONLY
102 LBF-FT TORQUE
.0048 INT. .0015 CL.
.0000 .0013 CL.
.0008 .0000 INT.
.0023 .0018 INT.
13.34 REF



ITEM	QTY	PART NUMBER	DESCRIPTION				
	1	R94-016956-001	HOUSING CAM BR'G				1
	2	R94-016915-001	THRUST WASHER				2
	3	R94-016916-001	COLLAR THRUST				1
	4	R94-016957-001	HOUSING THRUST B'G				1
	5	R94-035906-001	GEAR CAM SHAFT				1
	6	R94-016949-001	SHAFT DRIVE END				1
	7	C15-074212-001	BUSHING DRIVE END				1
	8	R94-016945-001	CAM SECTION				1
	9	R94-016950-001	BEARING FREE END				1
	10	R94-016958-001	HOUSING FREE END				1
	11	R94-016932-001	EXT. SHAFT ENCODER				1
	12	R94-016959-001	HOUSING ENCODER				1
	13	R94-042905-001	OIL SEAL				1
	14	R94-016960-001	COVER ENCODER				1
	15	R94-016976-001	COVER IDLER				1
	16	R94-019950-001	CAM IDLER SHAFT				1
	17	R94-035909-001	BEARING IDLER				2
	18	R94-035905-001	GEAR IDLER				1
	19	R94-035904-001	GEAR CAM IDLER				1
	20	R94-015023-042	CAPSCREW S.T. HD.		M12 x 40 LG.		6
	21	R94-016026-001	BEARING				1
	22	R94-015023-046	CAPSCREW S.T. HD.		M12 x 60 LG.		7
	23	R54-015905-001	TAPER PIN				6
	24	S2P-015665-072	CAPSCREW S.T. HD.		5/8 - 18 x 2 1/4		6
	25	R54-015909-003	PLAIN WASHER		Ø 5/8		6
	26	S2P-015665-088	CAPSCREW S.T. HD.		5/8 - 18 x 2 3/4		12
	27	S2P-076006-024	DOWEL PIN		Ø 3/8 x 75 LG		1
	28	S2P-015064-040	CAPSCREW S.T. HD.		1/2 - 13 x 1 1/8		4
	29	S2P-015064-056	CAPSCREW S.T. HD.		1/2 - 13 x 1 3/4		12
	30	S2P-015061-032	CAPSCREW S.T. HD.		1/4 - 20 x 1		6
	31	S2P-015061-048	CAPSCREW S.T. HD.		1/4 - 20 x 1 1/2		6
	32	S2P-015063-040	CAPSCREW S.T. HD.		3/8 - 16 x 1 1/4		4
	33	S2P-076006-052	DOWEL PIN		Ø 3/8 x 1.62 LG		1
	34	R94-042907-003	SPEEDY SLEEVE				1
	35	R94-016951-001	RETAINER RING				1
	36	R54-042904-002	OIL SEAL		Ø 4.5 SHAFT		2
	37	R94-042907-002	SPEEDY SLEEVE				1
	38	S2P-015063-064	CAPSCREW S.T. HD.		3/8 - 16 x 2		4
	39	C14-072157-001	BUSHING FREE END				1
	40						
	41	900-581600-125	SEALANT		LOCTITE #242		A/R
	42	SUC-581600-147	SEALANT		SILICONE #732		A/R

NOTE
- APPLY LOCTITE Pc (41) AT ASS'Y
- APPLY SILICONE Pc (42) BETWEEN TWO SURFACES
- REMOVE THIS FLANGE WITH SIDE CUTTERS AFTER POSITIONING
- ASSEMBLE SLEEVE WITH TOOL R94-047901 OR R94-047905
5- TORQUE VALUE ± 2%
6- YENSILE STRENGTH LEVEL OF SOCKET HEAD CAPSCREWS TO BE 180,000 P.S.I.

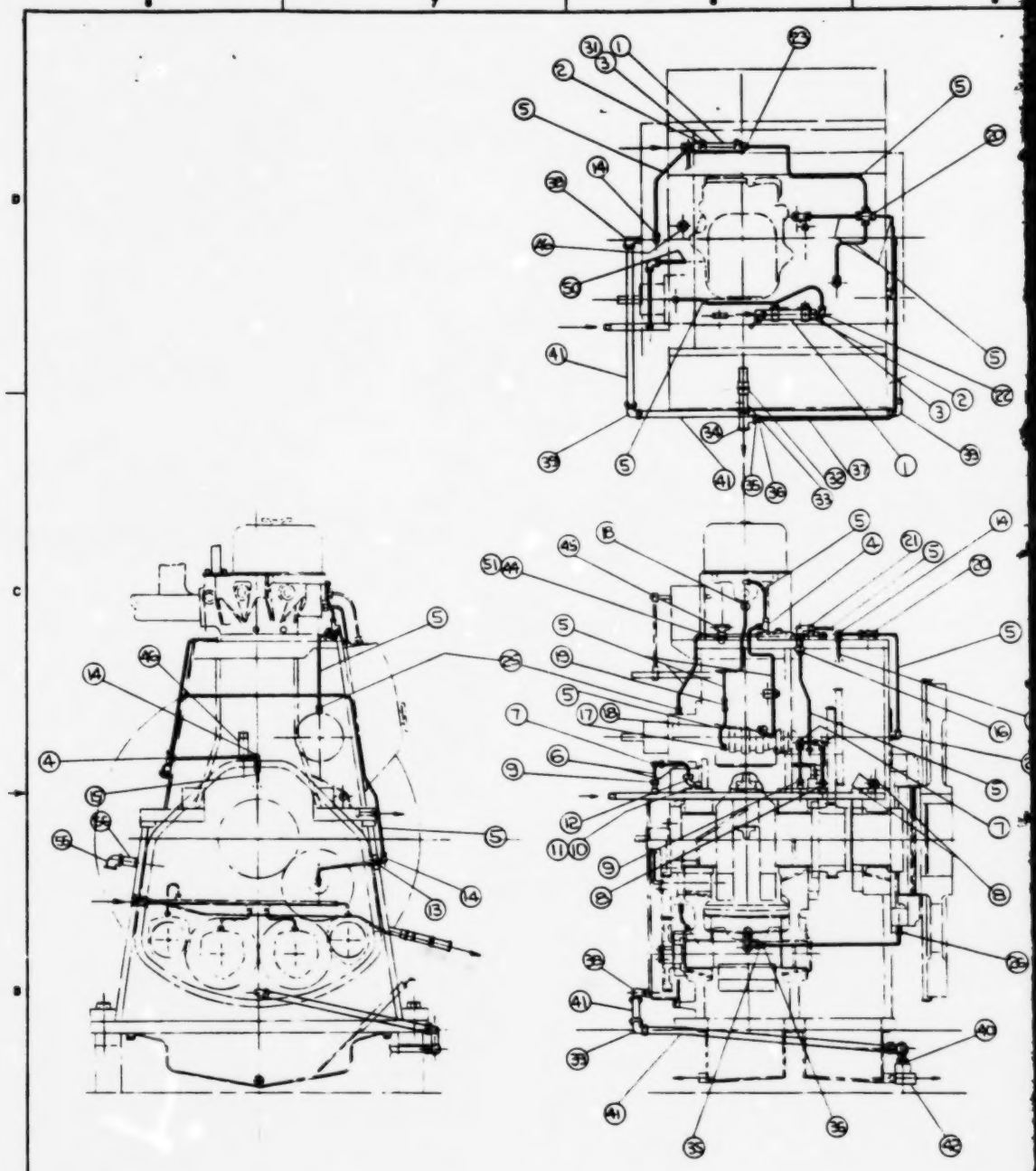
No.	Date	Description	Init.
Z		ECN N° 6-1931 INCORP.	

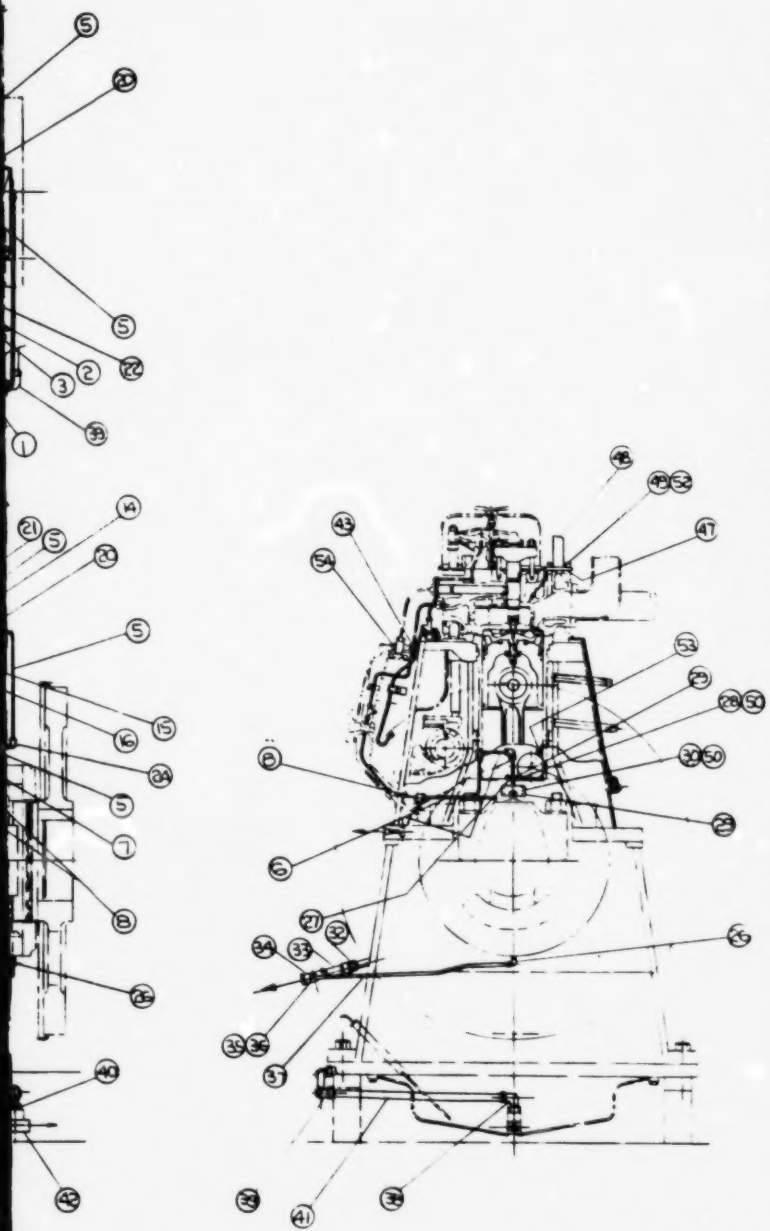
L.B. 89-02-22

R94-016931
R94-014979
AC
82

Bombardier Inc.
CAMSHAFT & DRIVE ASS'Y
FINAL ASSEMBLY
R94-016948
Z

FIGURE B.3





ITEM							
1	R94040919001	HEADER			-	2	
2	C4007244001	CLAMP				4	
3	92P0116240B0	SCREW CAP HEX		1/2-13NC x 2 1/2 LG		4	
4	900460991205	MALE RUN TEE		1/4 NPT EBMETO 7755-6		2	
5	R94040925905	TUBE	000623020430	Ø .350 O.D. X .049 W X 10 LG		1	
6	R94040925906	TUBE	000623121423	Ø 1.500 D X .065 W X 79 LG		1	
7	R94019912037	ELBOW		3/8 TUBE (SWAGELOK B-400-9)		3	
8	R94019912008	ELBOW		3/8 NPT X Ø 3/8 TUBE		3	
9	R94019912007	MALE CONN.		3/4 NPT X Ø 3/8 TUBE		2	
10	R94019912012	CLOSE NIPPLE		1/4 NPT		1	
11	R94015912003	ELBOW (HOSE FEM.)		3/8 NPT X 1/4 NPT		1	
12	R94015912009	ELBOW		3/4 NPT X Ø 3/8 TUBE		1	
13	900450900001	NIPPLE		1/8 NPT X 1 1/2 LG		1	
14	R94015912040	ELBOW FEMALE		1/8 NPT X Ø 3/8 TUBE		3	
15	R94040912001	SPRAY NOZZLE				2	
16	R94019912027	MALE CONN.		5/16-18 X Ø 3/8 TUBE (SWAGELOK B-600-6)		1	
17	900460850506	ELBOW MALE		45° 1/4 NPT EBMETO 7755-6		1	
18	900460990205	MALE CONN.		1/4 NPT EBMETO 7705-6		1	
19	900460600905	TEE		EBMETO CPG. TEE Ø 3/8 X Ø 3/8 X 1/4 NPT		1	
20	R94015912041	UNION FEM.		Ø 3/8 (SWAGELOK B-600-6)		1	
21	R94015912086	ELBOW		5/16-18 X Ø 3/8 TUBE (SWAGELOK B-6-8)		1	
22	R94015912042	ELBOW		1/4 NPT X Ø 3/8 TUBE (SWAGELOK B-400-9)		1	
23	R94015912006	MALE CONN		1/8 NPT X Ø 3/8 TUBE (SWAGELOK B-200-9)		1	
24	R94015912034	ELBOW		1/8 NPT X Ø 3/8 TUBE (SWAGELOK B-200-9)		1	
25	R94019912010	MALE CONN		3/8 NPT X Ø 3/8 TUBE (SWAGELOK B-600-6)		1	
26	R94015912035	MALE ELBOW		1/4 NPT X Ø 3/8 TUBE (SWAGELOK B-400-9)		1	
27	R94015919004	O RING		Ø 3/8		1	
28	R94039994001	RETAINING R.				1	
29	92P0116220B4	HEX BOLT (SPECIAL)		5/16-18NC x 3/4 LG.		6	
30	R94039995001	COVER				1	
31	91P0855040B	LOCKWASHER		SIZE 1/2		4	
32	900455400157	COUPLING		SIZE 1 1/4		1	
33	900459090158	NIPPLE		SIZE 1 1/4 X 5 LG		1	
34	900453000081	TEE		SIZE 1 1/4 X 1 1/4 X 1/2		1	
35	900454600106	BUSHING		SIZE 1/2 TO 1 NPT		1	
36	R94015912043	MALE CONN		1 NPT X Ø 1 TUBE (SWAGELOK 1610-16)		1	
37	R94040925937	TUBE	000623121123	Ø 1.500 O.D. X .065 W X 60° LG		1	
38	R94015912044	MALE ELBOW		1 NPT X Ø 1 TUBE (SWAGELOK 1610-16)		2	
39	R94015912045	UNION ELBOW		Ø 1 TUBE (SWAGELOK 1610-16)		2	
40	900454500562	BUSHING		SIZE 1 1/2 TO 1 NPT		1	
41	R94040925944	TUBE	000623121423	Ø 1.00 O DX .065 W X 110 LG		1	
42	R94015912046	TEE (PIPE THRD)		1 1/2 NPT (NEWAGE 8052-24-24S)		1	
43	C1507672B001	STOPPER				1	
44	R94015912014	MALE CONN		3/4-16 X 1 1/16-14 (NEWAGE 19-1810-12)		1	
45	R94015912013	MALE TEE CONN		3/4-16 (NEWAGE 20W17-8-8S)		1	
46	900450900183	NIPPLE		1 1/2 NPT X 6 LG		1	
47	900589600155	SEALANT		LOCTITE 12336		A/R	
48	R94040921001	BRANCH PIPE				1	
49	92P0116260A0	CAPSCREW HEX		5/8-11NC x 1 1/4 LG		3	
50	900589030208B	SILICON				A/R	
51	R94015912024	O RING		CATON S-8-85-2V		1	
52	900589600225	SEALANT		LOCTITE 242		A/R	
53	R94015912028	MALE CONN		1/8 NPT X Ø 3/8 TUBE (SWAGELOK)		1	
54	C1507672100X	GROMMET				1	
55	900459600061	ELBOW		1/2 x 90 DEG		1	
56	900450900175	NIPPLE		1/2 NPT X 4 LG		1	

NOTES:
1- THIS DWG. SHOWS PIPING REQUIRED AND ON APPROXIMATE INDICATION OF HOW IT SHOULD RUN. PIPE FITTER SHALL USE HIS OWN INITIATIVE TO RUN TUBING PROPERLY AND NEATLY AND FASTEN WHERE NECESSARY.
2- ALL TUBING SHALL BE CUT AND BENT AT ASSY. TUBE ENDS MUST BE DEBURRED AND NO LOOSE CHIPPINGS INSIDE TUBES OR FITTINGS.

Z	ECN°G-1914 INCORP.	
Y	ECN°G-1977 INCORP.	

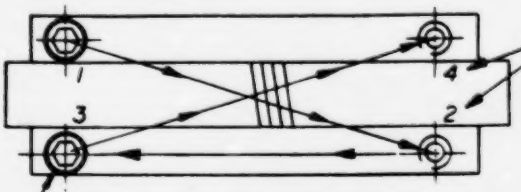
R94 040920
R94 014979
1-251 LOE AO

Bombardier Inc.
Bombardier Produits Récréatifs et Aéronautique Produits Motorisés Sea-Doo Division
Valcourt, Québec, Canada

TUBE OIL HEADERS ASS'Y TO ENGINE
BLUE GEAR BEAR SPRAY

R94-040925 Y

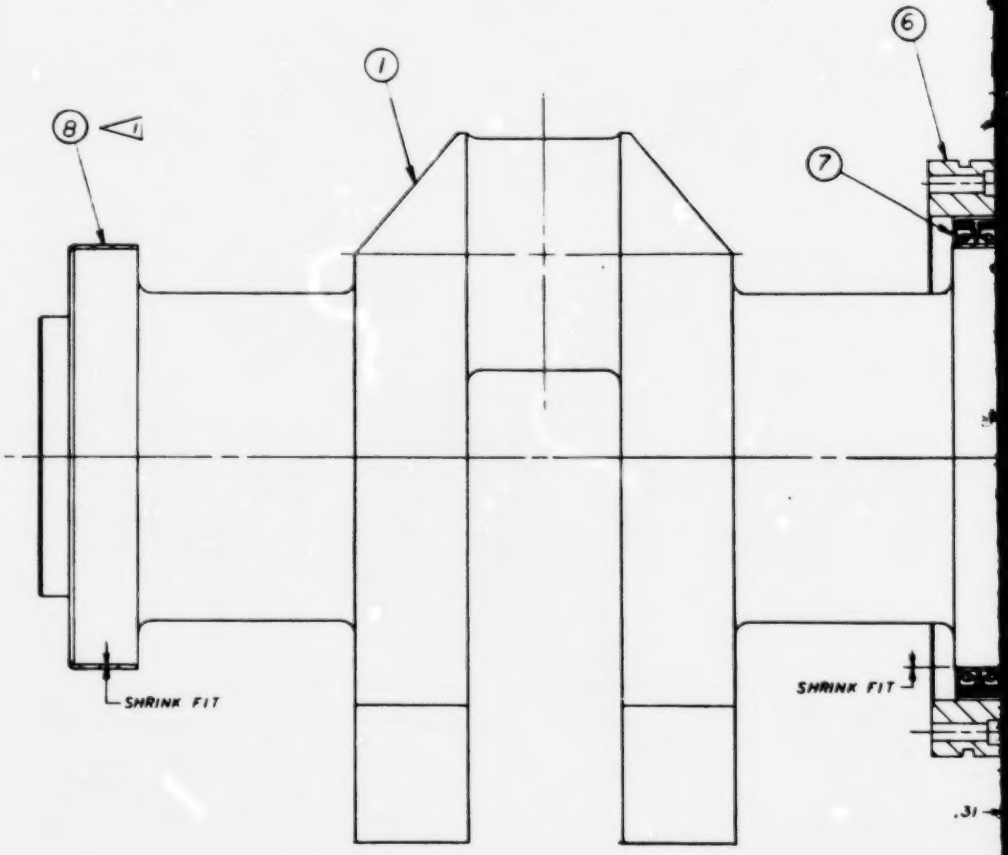
FIGURE B.4



NUMBERS IND
SEQUENCE OF
TIGHTENING

INSTRUCTIONS FOR GEAR INSTALLATION

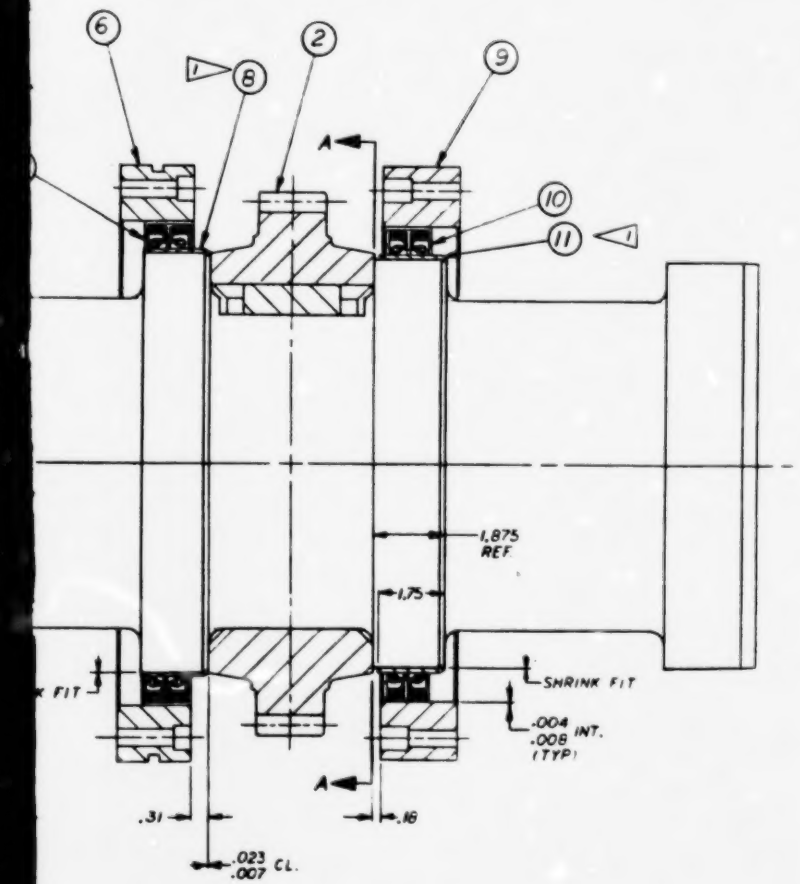
LUBRICATE ALL FACES SEATS AND THREADS WITH ENGINE LUBRICATING OIL TIGHTEN ALL BOLTS EVENLY TO 50 LB-FT TORQUE, THEN TIGHTEN ALL BOLTS TO 200 LB-FT TORQUE IN THE SEQUENCE INDICATED.

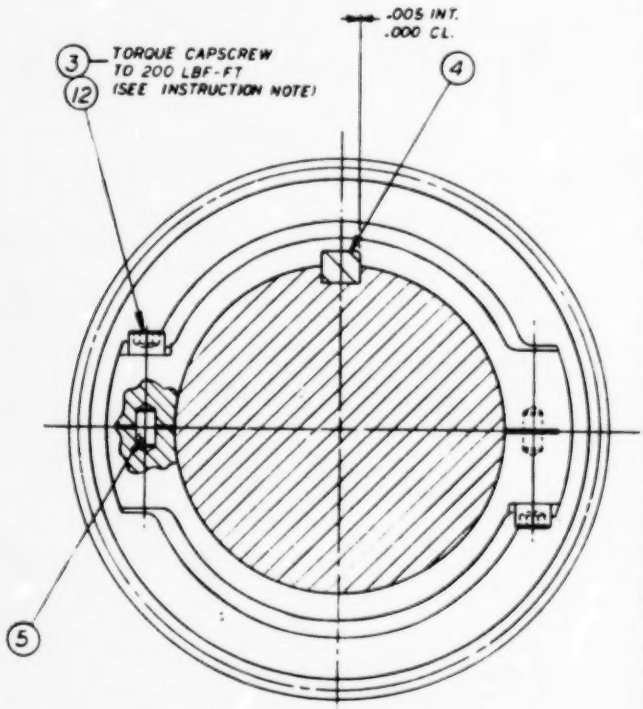


Rév	Zone	Description	Ind°	Rév	Zone	Description	Ind°	Rév	Zone	Description	Ind°	Rév

NUMBERS INDICATE SEQUENCE OF BOLT TIGHTENING

	1	R94-019931-001	CRANKSHAFT				1		
	2	R94-035907-001	SPLIT GEAR				1		
	3	R94-015911-001	CAPSCREW SK HD		5/8-18 NF-3A x 4 LG.		4		
	4	92P-078008-080	KEY		1 x 3/4 x 2 1/2		1		
	5	92P-076011-032	DOWEL		ø 1/2 x 1 LG		2		
	6	R94-019934-001	RETAINING RING				1		
	7	R94-042903-002	SEAL		ø 11.0 SHAFT		1		
	8	R94-042906-002	WEAR SLEEVE				2		
	9	R94-019935-001	RETAINING RING				1		
	10	R94-042903-001	SEAL		ø 10.750 SHAFT		1		
	11	R94-042906-001	WEAR SLEEVE				1		
	12	900-581600-114	SEALANT		LOCTITE "271		A/R		





SECTION "A-A"

INSTRUCTION NOTE:

1 HEAT THE WEAR SLEEVE FROM 350°F TO 400°F (MAX.) & SEE DWG. R94-042906

L.B. 88-03-25

PROJECTION

TOLÉRANCE ET FINI DE SURFACE SAUF INDICATION CONTRAIRE

MÉTRIQUE

MATÉRIAL

FRAC (MACH.) ± 1/32 ±1/16

DÉCIMAL ± .005 ±.010

FRAC (BRUT) ± 1/16 ± 1/8

ANGLES ±1/2° CHANFREIN ±2°

ÉBARBER 1/64" / 0.4mm MAX

FINI DE SURFACE 1.25 mu m / 99

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Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal Quebec Canada

CRANKSHAFT & GEAR ASS'Y

MAIN BASE ASS'Y

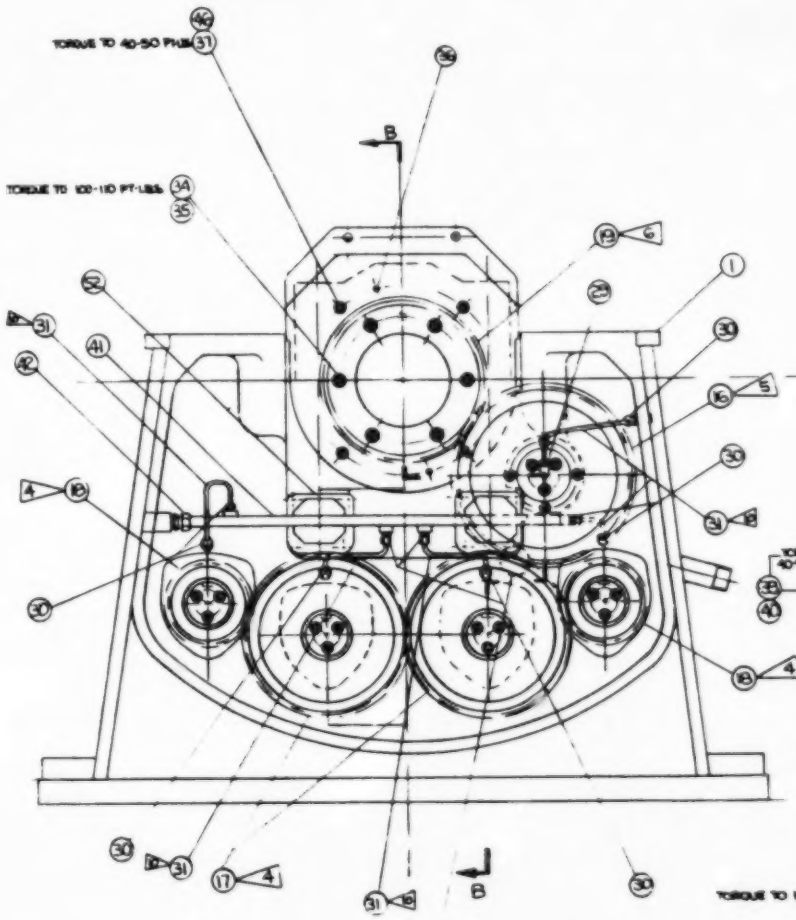
R94-019933

1/251 L.O.E. A1

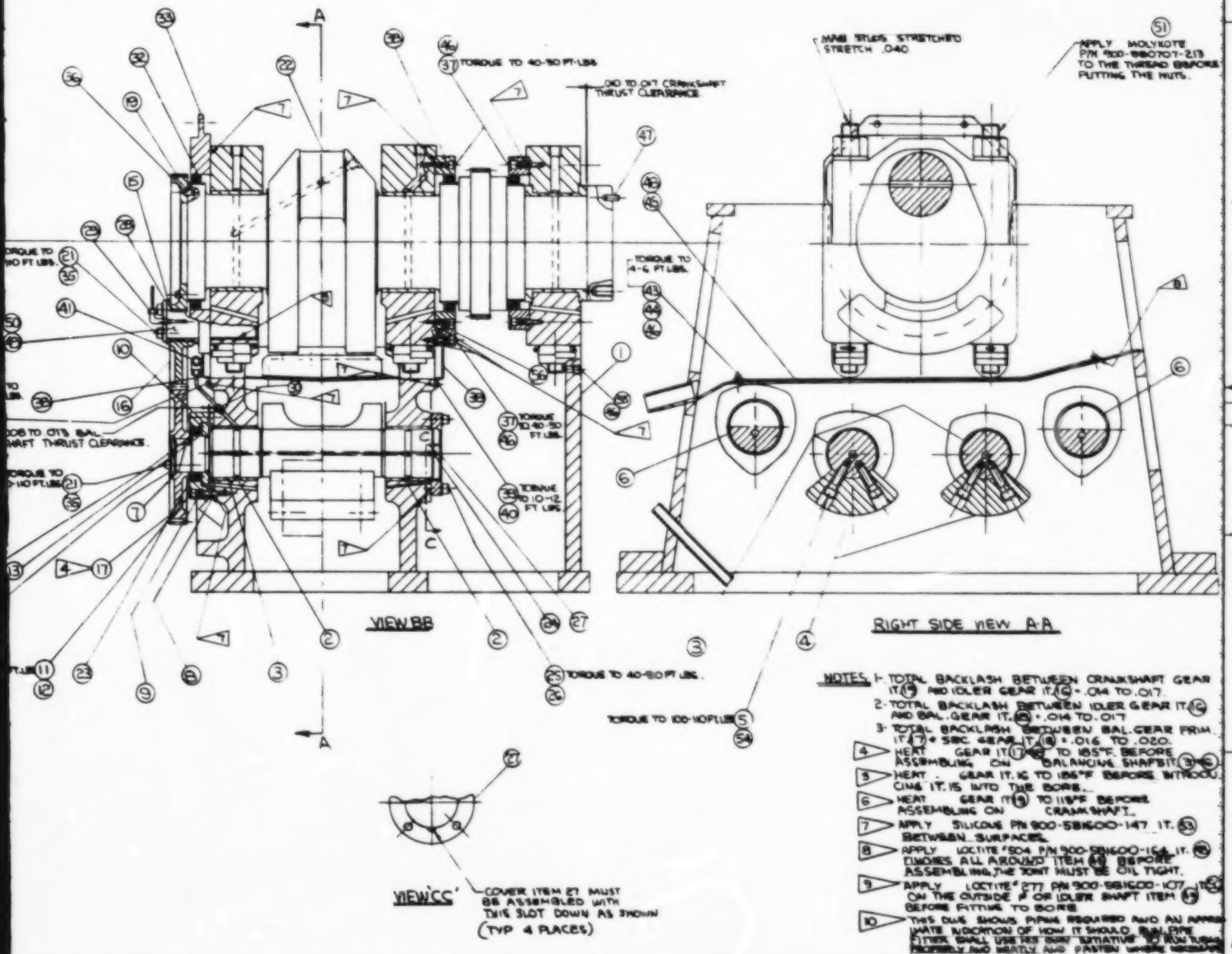
1:2

/ R94-019932

FIGURE B.5



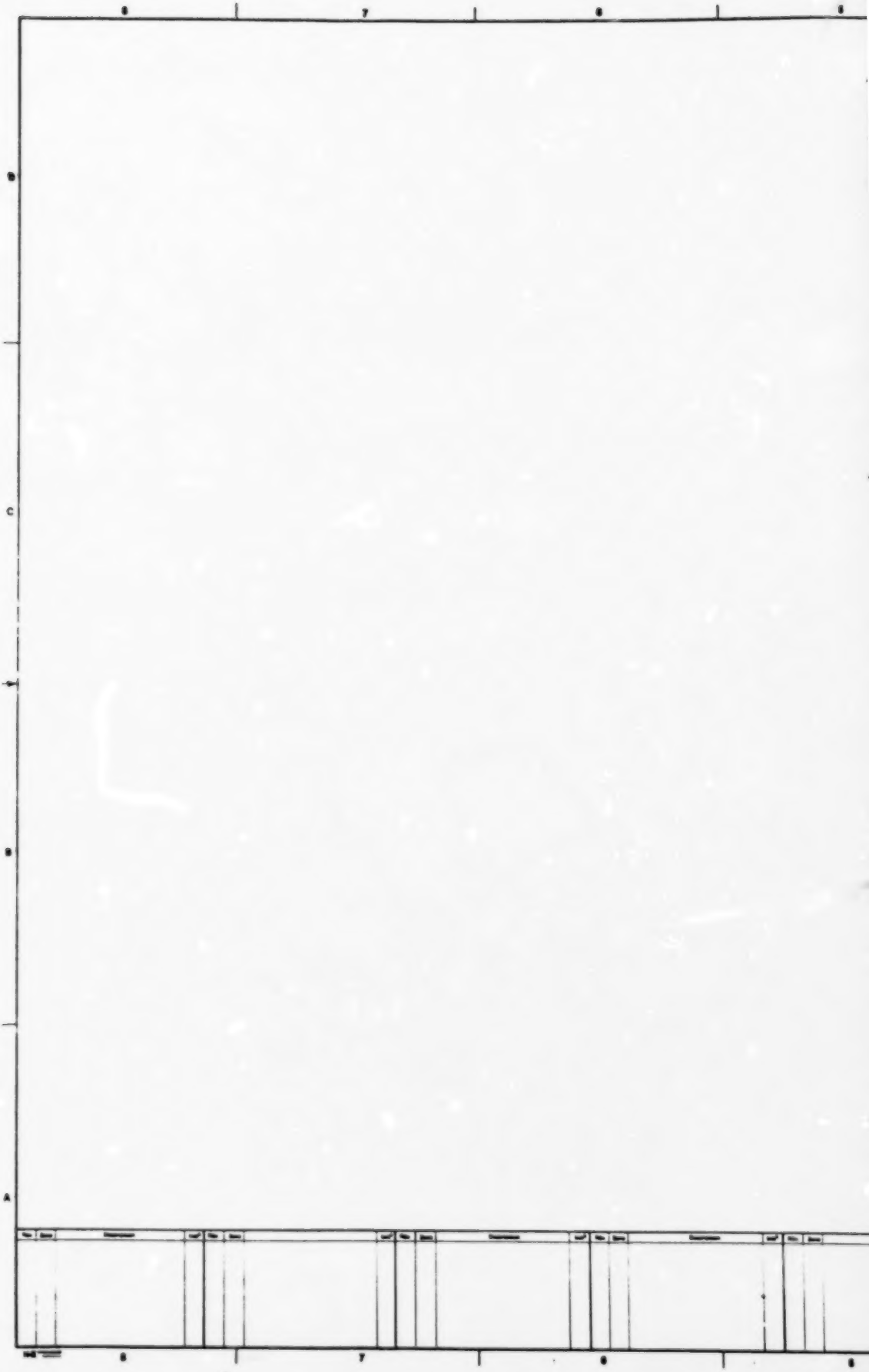
ALL KEYWAYS OF THE BALANCING SHAFTS & THE DOWEL OF THE CRANKSHAFT (7,47) SHOULD BE LOCATED UPWARD WITHIN ONE PITCH BEFORE MESHING THE GEARS ITEMS (5)(7)(9)(13) TOGETHER. AFTER PRICK PUNCH THE GEARS AS SHOWN.


MAIN STUDS STRETCHED STRETCH .040
APPLY MOLYKOTE P/N 900-980707-213 TO THE THREAD BEFORE PUTTING THE NUTS.
TORQUE TO 40-50 FT-LBS
.010 TO .017 CRANKSHAFT THRUST CLEARANCE
TORQUE TO 4-6 FT LBS.
TORQUE TO 40-50 FT LBS.
TORQUE TO 10-12 FT LBS
TORQUE TO 40-50 FT LBS.
TORQUE TO 100-140 FT LBS.
VIEW BB
RIGHT SIDE VIEW A-A
VIEW CC
COVER ITEM 27 MUST BE ASSEMBLED WITH THIS SLOT DOWN AS SHOWN (TYP 4 PLACES)

NOTES:
1. TOTAL BACKLASH BETWEEN CRANKSHAFT GEAR IT. (1) AND IDLER GEAR IT. (2) = .014 TO .017
2. TOTAL BACKLASH BETWEEN IDLER GEAR IT. (2) AND BAL. GEAR IT. (3) = .014 TO .017
3. TOTAL BACKLASH BETWEEN BAL. GEAR PRIM. IT. (7) & SEC. GEAR IT. (8) = .016 TO .020.
4. HEAT GEAR IT. (1) & (2) TO 185°F. BEFORE ASSEMBLING ON BALANCING SHAFTS IT. (3) & (5)
5. HEAT GEAR IT. 16 TO 185°F BEFORE INTRODUCING IT. 15 INTO THE BORE.
6. HEAT GEAR IT. (4) TO 118°F BEFORE ASSEMBLING ON CRANKSHAFT.
7. APPLY SILICONE P/N 900-581600-147 IT. (53) BETWEEN SURFACES.
8. APPLY LOCTITE "504 P/N 900-581600-164 IT. (52) ENDS ALL AROUND ITEM (49) BEFORE ASSEMBLING. THE JOINT MUST BE OIL TIGHT.
9. APPLY LOCTITE "277 P/N 900-581600-107 (50) ON THE OUTSIDE Ø OF IDLER SHAFT ITEM (9) BEFORE FITTING TO BORE
10. THIS DWG SHOWS P/NUMBERS REQUIRED AND AN APPROXIMATE LOCATION OF HOW IT SHOULD BE WIRED. EITHER SHALL USE RESOURCE DISCRETION TO RUN WIRES PROPERLY AND NEATLY AND PROVIDE WHERE NECESSARY

R94-014978	A0	MAIN BASE ASS'Y L.O.E.	
1/29/08			R94-019933

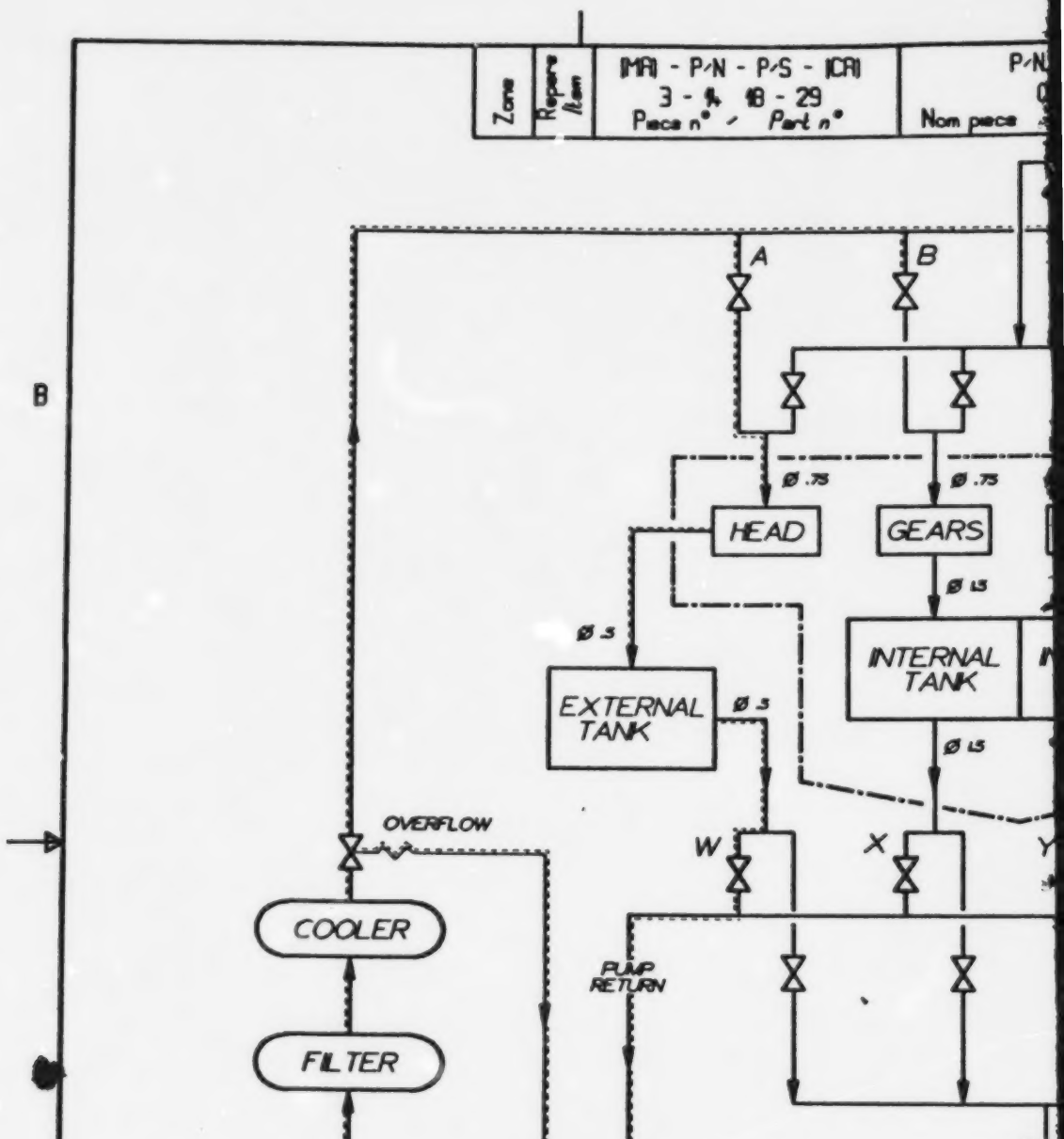
FIGURE B.6.1



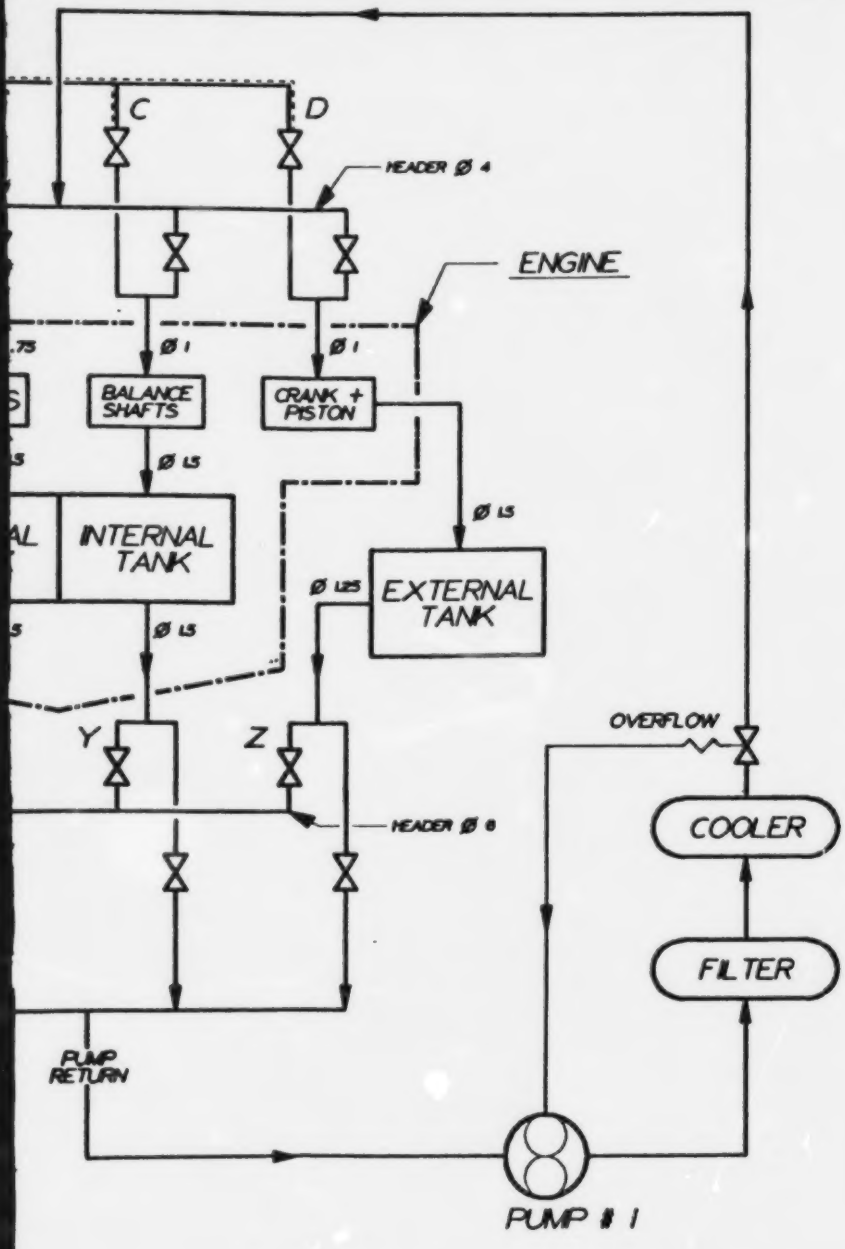
ITEM	PART NUMBER	DESCRIPTION	REFERENCE	SPECIFICATION	QTY
1	R94014974001	MAIN BASE			1
2	C1407215T001	BUSHING			8
3	R94019941001	PRIM BAL SHAFT			2
4	R94019947001	BAL WT.			2
5	92P0150660S6	CAPSCREW SCHD		3/8-16UNC x 3/4 LG.	8
6	R94019942001	SEC BAL SHAFT			2
7	R94019917001	KEY		5/16 x 1/2	4
8	R94019948001	SPACER			4
9	R94019935001	THRUST WASHER			4
10	R94019940001	RETAINER			4
11	92P0150640S6	CAPSCREW SCHD		1/2-13UNC x 3/4 LG	12
12	91P0835050S6	SP L WASHER		SIZE 1/2	12
13	R94015919001	"O" RING			4
14	R94019938001	SPACER			4
15	R94019939001	BEARING			2
16	R94036901001	IDLER GEAR			1
17	R94036902002	GEAR (PRIM BAL SH)			2
18	R94036903002	GEAR (SEC BAL SH)			2
19	R94035900001	GEAR (CRANK)			1
20	R94019911001	THRUST R.			4
21	92P0150640S2	CAPSCREW SCHD		1/2-13UNC x 1 1/4 LG	15
22	R94019932001	CRANKSHAFT ASSY			1
23	R94042904001	SEAL		3 1/4 x 4 5/8 x .437 CRWI	8
24	90048620000S	PLUG PIPE		1/8 SQ HD.	4
25	92P0150630S6	CAPSCREW SCHD		5/16-18UNC x 1 3/4 LG	16
26	91P0830020S6	WASHER		SIZE 5/16	32
27	R94019949001	COVER			4
28	R94019910001	THRUST R.			1
29	R94015912029	MALE ELBOW		3/8 NPT x 1/4 TUBE	2
30	R94015912033	MALE CONN.		3/8 NPT x 1/4 TUBE	8
31	R94019939931	TUBE	000623202.17	Ø1/4 x .035W x 80 LG	A/R
32	R94042903002	SEAL		11 x 12 1/2 x 1.25 HDSD2	1
33	R94019946001	RETAINER RING			1
34	92P0150640S6	CAPSCREW SCHD		1/2-13UNC x 1 3/4 LG	6
35	91P0830020S8	WASHER		SIZE 1/2	21
36	92P0760110S2	DOWEL		Ø1/2 x 1 LG	1
37	92P0150630S4	CAPSCREW SCHD		5/16-18UNC x 2 LG	16
38	R94015919002	"O" RING			1
39	92P0150610I6	CAPSCREW SCHD		1/4-20UNC x 1/2 LG	16
40	91P0830020I4	WASHER		SIZE 1/4	16
41	R94040928001	HEADER ASSY			1
42	R94015912047	MALE CONN		1/4 NPT x 5/16 TUBE	1
43	R94015920001	CAPSCREW SCHD		#10-32UNF x 3/8 LG.	22
44	91P0830020I0	WASHER		#10 SIZE	22
45	R94014994001	COVER			1
46	90058160017S	LOCTITE #242			A/R
47	92P0760260S2	DOWEL		Ø3/8 x 1 LG	1
48	90058160016A	LOCTITE #504			A/R
49	R94019951001	IDLER SHAFT			1
50	90058160D107	LOCTITE #277			A/R
51	90058070723	MOLYKOTE			A/R
52	R94015916001	COVER			4
53	90058160014	SILICONE			A/R
54	90058160011A	LOCTITE #271			A/R
55	90045660016	PLUG PIPE		1/4 HEX SOC HD	5
56	R94019936001	SEAL RING			1

	R94014979	Bombardier Inc.	MAIN BASE ASSY
	1-251 LOE AO		L.O.E.
	1:4 1/4		R94-019933

FIGURE B.6.2


Zone
Repere Item
IMAI - P/N - P/S - ICRI
3 - 4 - 18 - 29
Piece n° - Part n°
P/N
Nom piece
A
B
B
Ø .75
Ø .75
HEAD
GEARS
Ø 1.5
Ø .5
INTERNAL TANK
EXTERNAL TANK
Ø .5
Ø 1.5
OVERFLOW
W
X
Y
COOLER
FILTER
PUMP RETURN
PUMP # 2
A

P/N (MA) 001 / Part name	P/N (MA) 047 Matière / Raw Matl	P/N (MA) 062 Description	Masse Mass	P-SOR 003 Qte/Qty	P-MFR 053 U/M	P-MFR 037 Approv.



LEGEND :

——— MAIN CIRCUIT

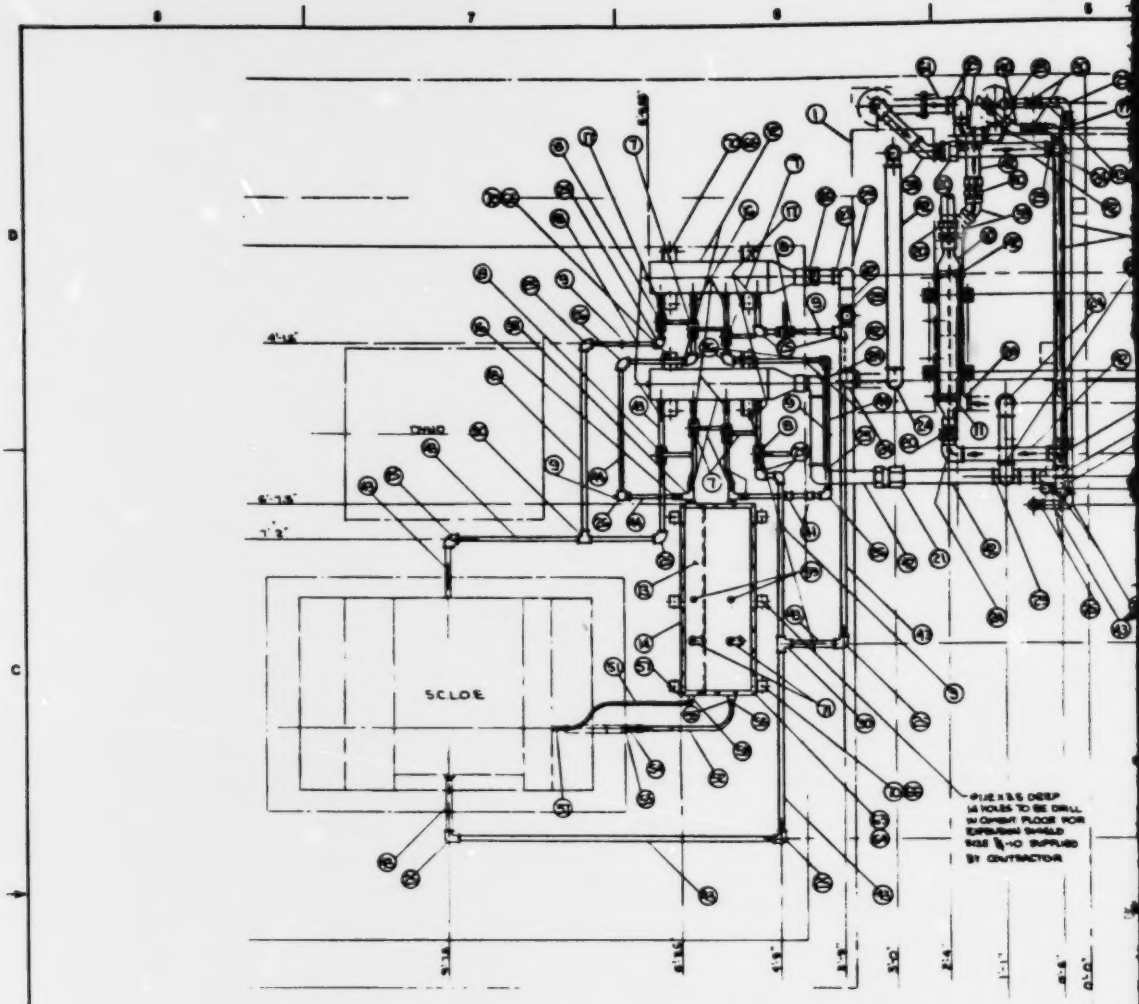
- - - - - - AUX. CIRCUIT

B

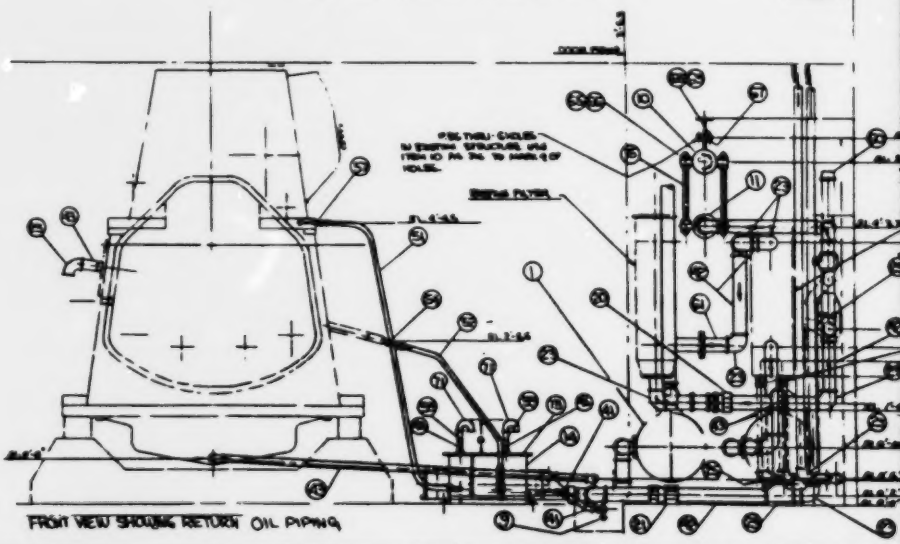
A

Dessinateur M.M. Date 890207	PROJECTION :	Ce plan ne doit être reproduit ni copié sans l'autorisation de Bombardier Inc. The drawing may not be reproduced or copied without the consent of Bombardier Inc.	Bombardier Inc Division des produits ferroviaires et diesel Rail and Diesel Products Division Montreal, Quebec, Canada	
Vérificateur Date	TOLERANCE ET FINI DE SURFACE SAUF INDICATION CONTRAIRE DEC. (MACH) 0.00 = ± 0.02, 0.000 = ± 0.01	No. reference		
Ch. groupe / Manager Date		No. ensemble / Assembly No.	Objet / Subject L.O.E. - ENGINE FOUR CIRCUIT LUBRICATING OIL FLOW DIAGRAM	
Document Date	DEC. (BRUT) ± .06 ANGLES : ± 1/4° CHANFREIN ± 2° EBARDER ± 1/64 FINI DE SURFACE : 125 mu in	No. modèle 1-251 L.O.E. A3	Pour / For	
		No. commande / Sales Order No. Ech./Sc. None	Folio	Plan No. / Drawing No. R94-058903 Revision

FIGURE B.7



TOP VIEW SHOWING RETURN OIL PIPING



FRONT VIEW SHOWING RETURN OIL PIPING

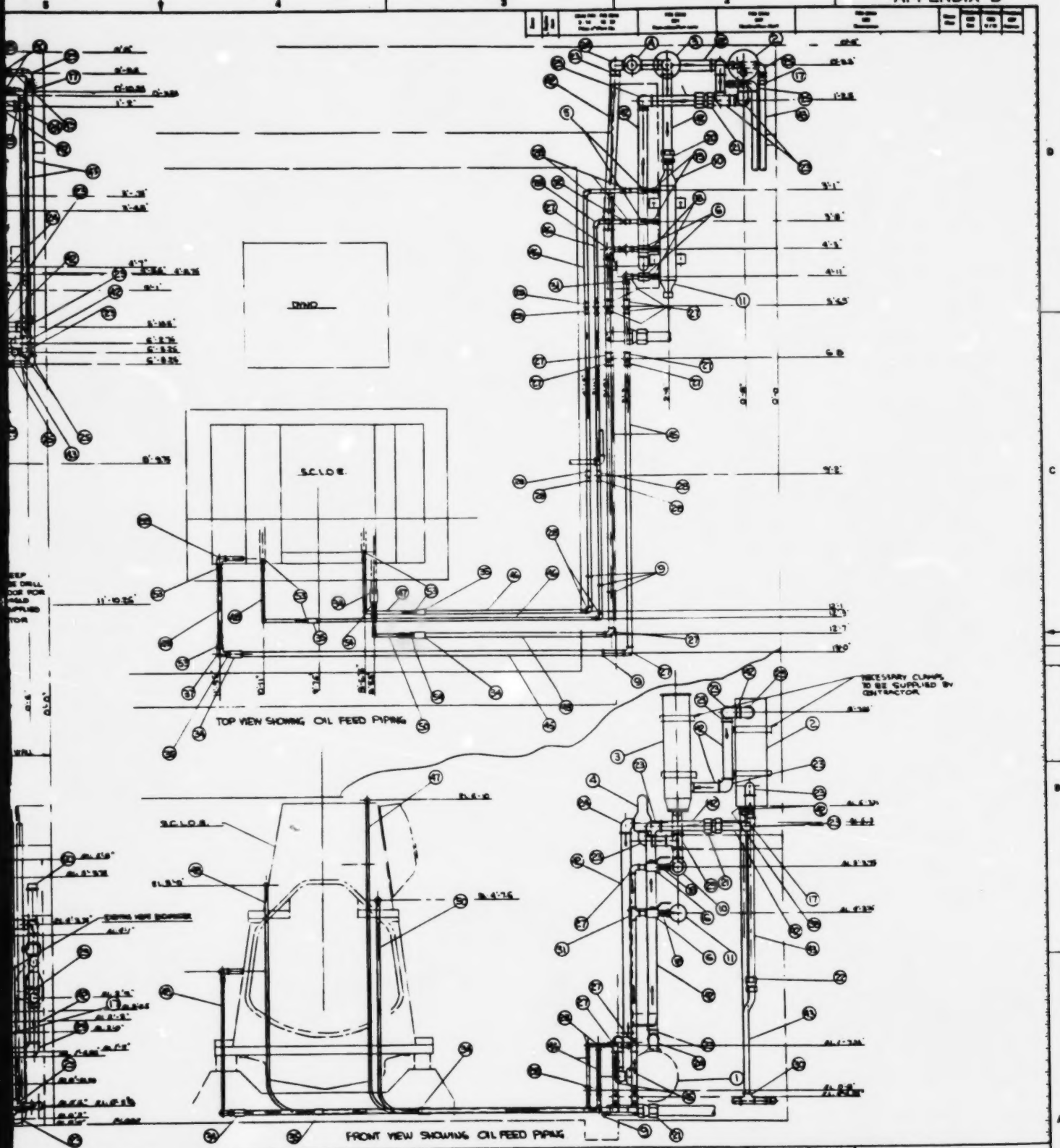
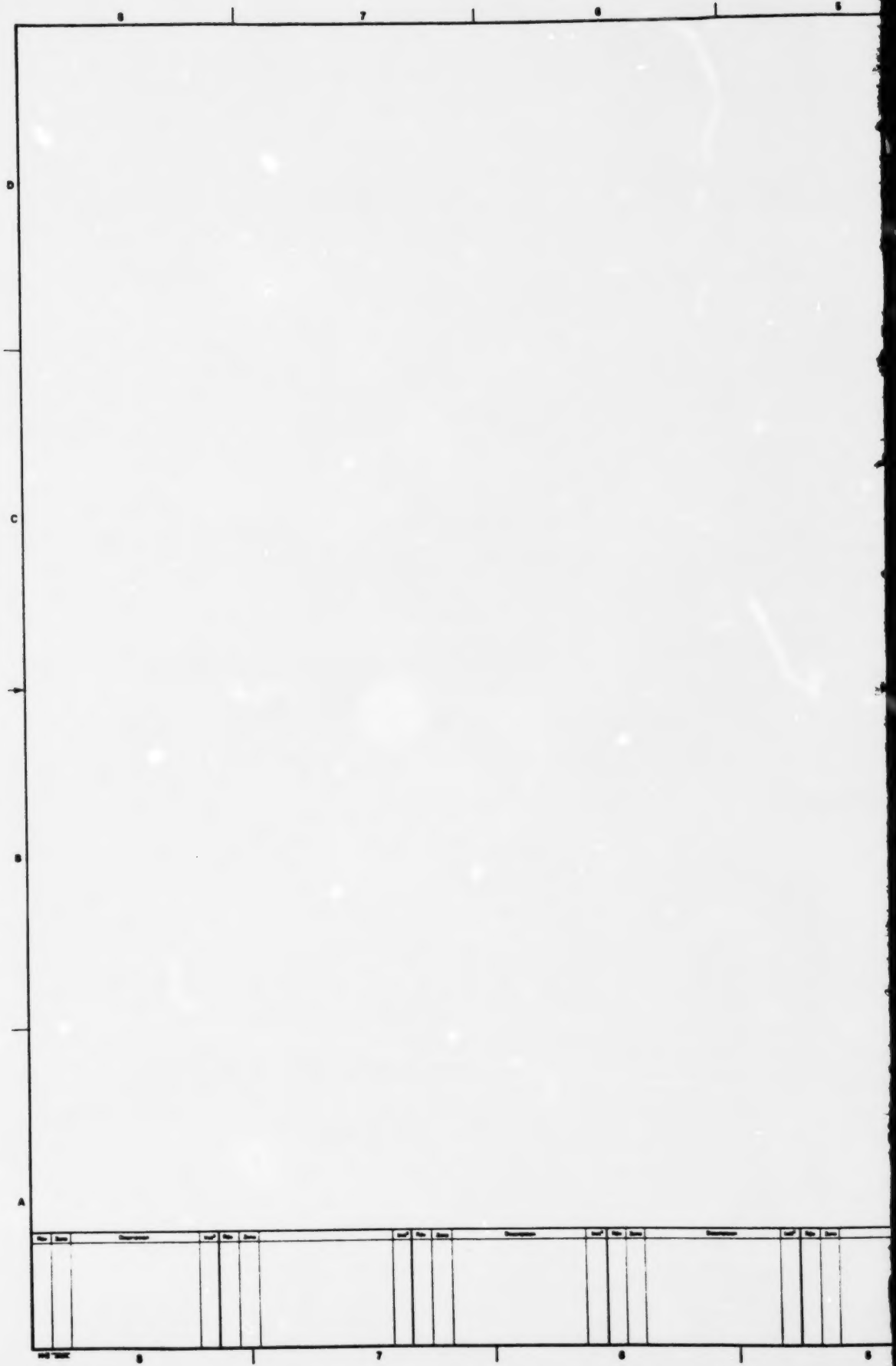

TOP VIEW SHOWING OIL FEED PIPING
FRONT VIEW SHOWING OIL FEED PIPING
LUBE OIL SYSTEM
FOR TEST CELL "5"
R94-030910

FIGURE B.8.1


8
7
6
5
D
C
B
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No.
Date
Description
8
7
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5

	1	900581607108	LUBE OIL PUMP		2x2 MODEL L124, FLANGED		1	
	2	900580807004	HEAT EXCHANGER		BCF 06-024 REF N°		1	
	3	9720529004601	FILTER	(ELEMENT ONLY N° 11-003)	2NPT- NORDYNE OR N° 1856-1 REF.		1	
	4	900458402981	RELIEF VALVES		3 NPT - CRANE N° 26 11 REF.		1	
	5	900458402971	BALL VALVE		APOLLO N° 70-104 REF ¼ NPT		4	
	6	900458402978	BALL VALVE		APOLLO N° 70-105 REF. ¾ NPT		4	
	7	900458402979	BALL VALVE		APOLLO N° 70-106 REF 1¼ NPT		4	
	8	900458402980	BALL VALVE		APOLLO N° 70-107 REF 1½ NPT		4	
	9	900458600019	GAUGE COCK		CRANE N° 708 REF ¼ NPT		9	
	10	R940149970001	MANIFOLD				1	
	11	R940149980001	MANIFOLD				1	
	12	R940149990001	MANIFOLD				2	
	13	R940149960001	COVER				1	
	14	R940149950001	OIL TANK				1	
	15	R940159210001	STUD				4	
	16	R940159220001	ADAPTER	(⅛ NPT)	AEROQUIP N° 2045-20-203		8	
	17	R940159220002	ADAPTER	(1½ NPT)	AEROQUIP N° 2045-24-245		9	
	18	R940159220003	ADAPTER	(1 NPT)	AEROQUIP N° 2045-16-165		4	
	19	R940159220004	ADAPTER	(¾ NPT)	AEROQUIP N° 2045-12-125		4	
	20	R940159220005	ADAPTER	(2 NPT)	AEROQUIP N° 2045-32-325		5	
	21	R940159220006	ADAPTER	(2 NPT)	AEROQUIP N° 2046-32-325		2	
	22	R940159220007	ADAPTER	(1½ NPT)	AEROQUIP N° 2046-24-245		1	
	23	900451600071	ELBOW		2 x 90 DEG		18	
	24	900452100281	STREET ELBOW		2 x 90 DEG		9	
	25	900451600061	ELBOW		1½ x 90 DEG		20	
	26	900451600051	ELBOW		1¼ x 90 DEG		8	
	27	900451600041	ELBOW		1 x 90 DEG		18	
	28	900451600031	ELBOW		¾ x 90 DEG		17	
	29	900453000121	TEE		2 NPT		4	
	30	900453000112	TEE		1½ NPT		4	
	31	900453000061	TEE		1 NPT		2	
	32	900455300004	TEE		¾ NPT		2	
	33	R940159220008	ADAPTER	(⅛ NPT)	AEROQUIP N° 2045-20-205		2	
	34	900455400156	COUPLING		1 NPT		3	
	35	900455400155	COUPLING		¾ NPT		2	
	36	R940159220009	REDUCER	(1 TO ¾ NPT)	AEROQUIP N° 2081-16-125		1	
	37	900452100281	STREET ELBOW		¾ x 90 DEG		1	
	38	R940159220010	REDUCER	(2 TO 1½ NPT)	AEROQUIP N° 2081-32-245		2	
	39	900451900081	45° ELBOW		2 NPT		3	
	40	900451900071	45° ELBOW		1½ NPT		1	
	41	900451900061	45° ELBOW		1¼ NPT		2	
	42	R940309109942	PIPE	0004500000009	2.0 X .154 WALL X 40'-0 LG		1	
	43	R940309109943	PIPE	0004500000008	1.5 X .145 WALL X 75'-0 LG		1	
	44	R940309109944	PIPE	0004500000007	1.25 X .140 WALL X 15'-0 LG		1	
	45	R940309109945	PIPE	0004500000006	1.0 X .133 WALL X 40'-0 LG		1	
	46	R940309109946	PIPE	0004500000005	.75 X .113 WALL X 40'-0 LG		1	
	47	R940409310001	HOSE ASSY		.88 I.D. X 135 LG		1	
	48	R940409310002	HOSE ASSY		.88 I.D. X 111 LG		1	
	49	R940409310003	HOSE ASSY		.88 I.D. X 87 LG		1	
	50	R940409320001	HOSE ASSY		1.12 I.D. X 111 LG		1	
	51	R940409180004	HOSE ASSY		.41 I.D. X 72 LG		1	
	52	R940409320002	HOSE ASSY		1.12 I.D. X 63" L		1	
	53	R940159220011	ADAPTER	(⅜-24 TO ⅝-18)	AEROQUIP N° 2021-12-165		6	
	54	R940159220012	ADAPTER	(1-11½ TO 1⅝-12)	AEROQUIP N° 2021-16-205		3	
	55	R940159220013	REDUCER	(1⅝-11½ TO 1-11½)	AEROQUIP N° 2081-20-165		2	
	56	R940159220014	ADAPTER 90° ELBOW	(1-11½ TO 1⅝-12)	AEROQUIP N° 2024-16-205		1	
	57	R940159220015	ADAPTER	(⅜-24 TO ⅝-18)	AEROQUIP N° 2021-8-85		2	
	58	R940159220016	ADAPTER 90° ELBOW	(⅜-24 TO ⅝-18)	AEROQUIP N° 2024-8-85		1	
	59	R940349070003	OIL GAUGE				2	
	60	900456000108	CAP PIPE		2 NPT		1	
	61	R940409330004	PIPE ASSY				1	
	62							
	63	92P0116230249	SCREW CAP HEX		⅜-16 NC X ⅝ LG		26	
	64	91P083002016	WASHER		SIZE ⅜		26	
	65	91P065000022	HEX NUT		⅜-16 NC.		6	
	66	91P083002082	WASHER		SIZE ½		30	
	67	92P0116240402	SCREW CAP HEX		½-13 NC X 1¼ LG		6	
	68	91P065000018	HEX NUT		½-13 NC		6	
	69	91P083002018	WASHER		SIZE ½		6	
	70	92P0116271258	SCREW CAP HEX		⅜-16 NC X 4 LG		14	
	71	900456800003	RETURN BEND 180°		1 NPT		2	

NOTES

1- THIS DWG SHOWS PIPING REQUIRED AND ON APPROXIMATE LOCATION OF HOW IT SHOULD RUN. PIPE FITTER SHALL USE HIS OWN INITATIVE TO RAN PIPING PROPERLY AND NEATLY AND FASTEN WHERE NECESSARY.

2- ALL PIPING SHOULD BE CUT AND THREADED AT ASSY. NO LOOSE CHIPS INSIDE PIPES OR FITTINGS ARE ACCEPTABLE.

M. BORETSKY 11767

99.12.15

| | | | | | | | |

APPENDIX C

- BSCRE/LOE Test and Running-in Procedure
- Table C.1; 1-251 operating guide

APPENDIX C

BSCRE/LOE TEST AND RUNNING-IN PROCEDURE

TEST OBJECTIVE

The main objective of this test is to verify the isolation of the four lube oil compartments.

SUB-OBJECTIVE:

To perform the standard BSCRE running-in procedure.

METHODOLOGY

Single and double lip seals are used to prevent the flow of lube oil from one compartment to the others. Each compartment has its own oil circuit. Therefore, the valve train, power assembly, gear train and the balancing shafts can be lubricated independently. The crankshaft seals are the major concern since they isolate the power assembly and are subject to the highest engine oil pressure.

The seal operating parameters are:

-	Pressure tolerance	10 - 15 psi
-	Temperature	-40° - 204° C
-	Shaft surface speed	5000 fpm (maximum)

The camshaft and balancing shaft seals are subjected to much lower pressures and are smaller in diameter. The operating parameters are same as above, except for shaft surface speed which is: 3600 fpm (maximum).

The following procedure is intended to prevent overloading and heating of the seals (premature failure); it is also intended to ensure all oil circuits are thoroughly flushed prior to initial start-up.

ENGINE PREPARATION

A - Open all four oil drains
B - Remove all crankcase doors
C - Disable fuel system
D - Position piston at BDC

1: Make sure fresh oil supply is adequate; temperature to be 20°C minimum
2: Make sure all valves at intake-lube-oil manifold are closed (see flow diagram R94-058903)
3: Open valve [D] to power assembly lube oil (PALO)
4: Start main lube oil pump (MLOP) and observe oil-engine-in pressure gauge. Turn down valve [D] if pressure is above 15 psi
5: Maintain lowest pressure at which oil flows from piston for a period of 15 minutes and inspect crankshaft seals for leakage. Also verify the oil tightness of the separation plate
6: Increase pressure incrementaly in steps of 15 psi to 60 psi
7: Identify and record all locations where leaks are found
8: Record all pressures

Verification of the remaining three circuits should follow the same sequence as above, except making sure that the correct valve is actuated.

BARRING OVER OF ENGINE

After completion of the above routine, the engine should barred over with all valves at the manifold open.

NOTE: Pressure to be controlled to avoid splashing: Items 5 and 6 should be repeated.

9: Replace all covers and bar over engine with oil lubricating; oil system operating as normal.

RUNNING-IN

The established procedure as used on the previous BSCRE engines should be followed with all performance data recorded (see 1-251 Operating Guide).

REFERENCE DATA

- Drawing: R94-014979
- Drawing: R94-058903

TABLE C-1

1-251 OPERATING GUIDE

ENGINE SPEED [min-1]	TORQUE [nm]	-ATENIN- OUTPUT POWER [kw]	BOOST AIR TEMPERATURE [°C]	BOOST AIR PRESSURE [kPa]
400	214	9.0	45	10
500	334	17.5	45	10
600	481	30.2	50	15
700	654	48.0	55	25
800	855	71.7	65	40
900	1082	102.1	75	70
1000	1336	140.0	85	130
1100	1616	186.4	95	

SET POINT:		/	LIMIT:
LPPPOT	800 kPa	/	1000 kPa
LTENIN	80 °C	/	90°C
JTENOT	75°C	/	85°C
APENIN	As required	/	250 kPa
ATENIN	As required	/	105°C
ETENOT	- - - - -	/	550°C
FPPPOT	300 kPa	/	500 kPa
LT	Across engine	/	10°C
JT	Across engine	/	5°C

KEY TO MNEMONICS:

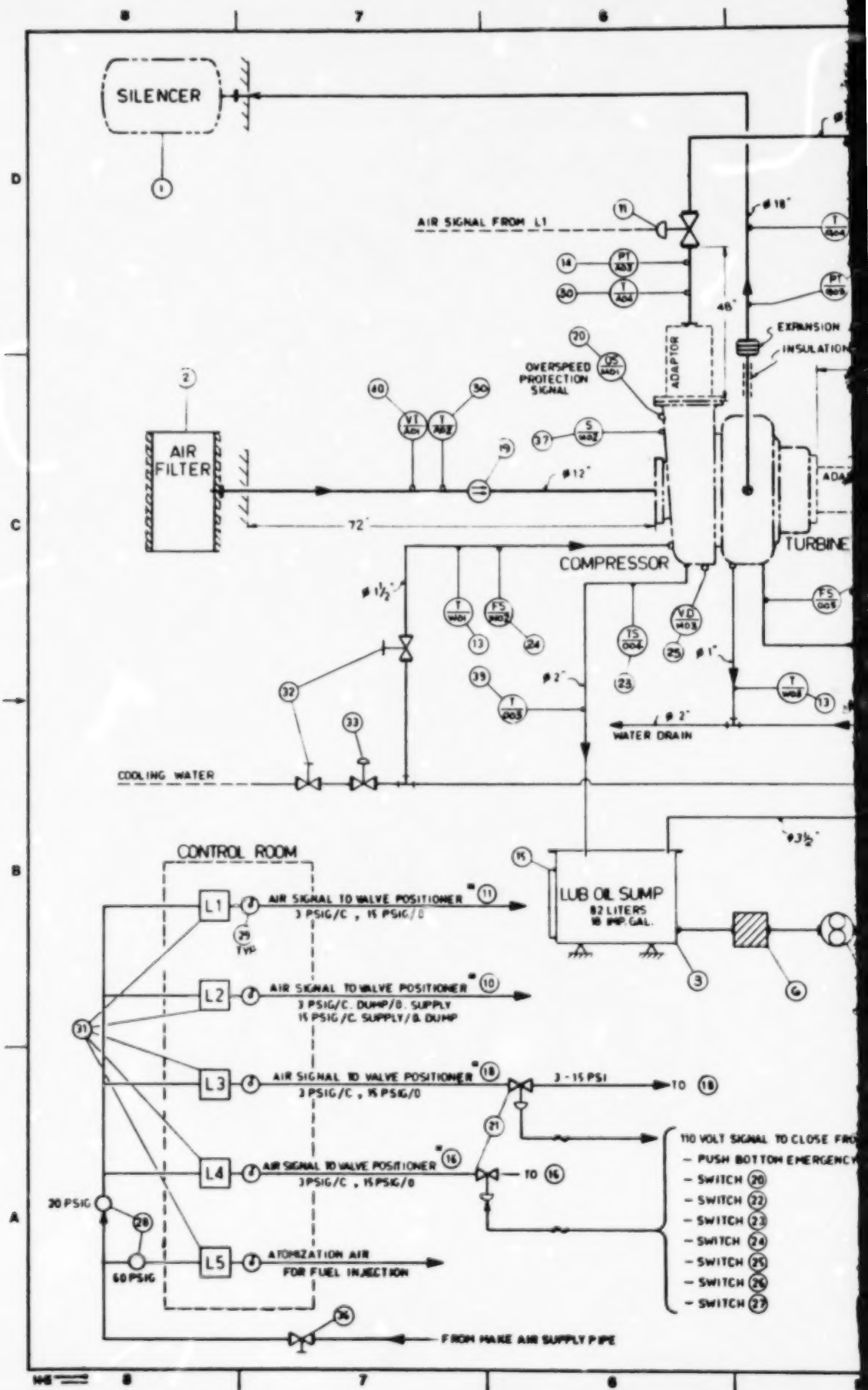
LPPPOT	=	Lube Pressure Pump Out
LTENIN	=	Lube Temperature Engine In
JTENON	=	Jacket Temperature Engine Out
APENIN	=	Air Pressure Engine In
ATENIN	=	Air Temperature Engine In
ETENOT	=	Exhaust Temperature Engine Out
FPPPOT	=	Fuel Pressure Pump Out
LT	=	Lube Temperature
JT	=	Jacket Temperature

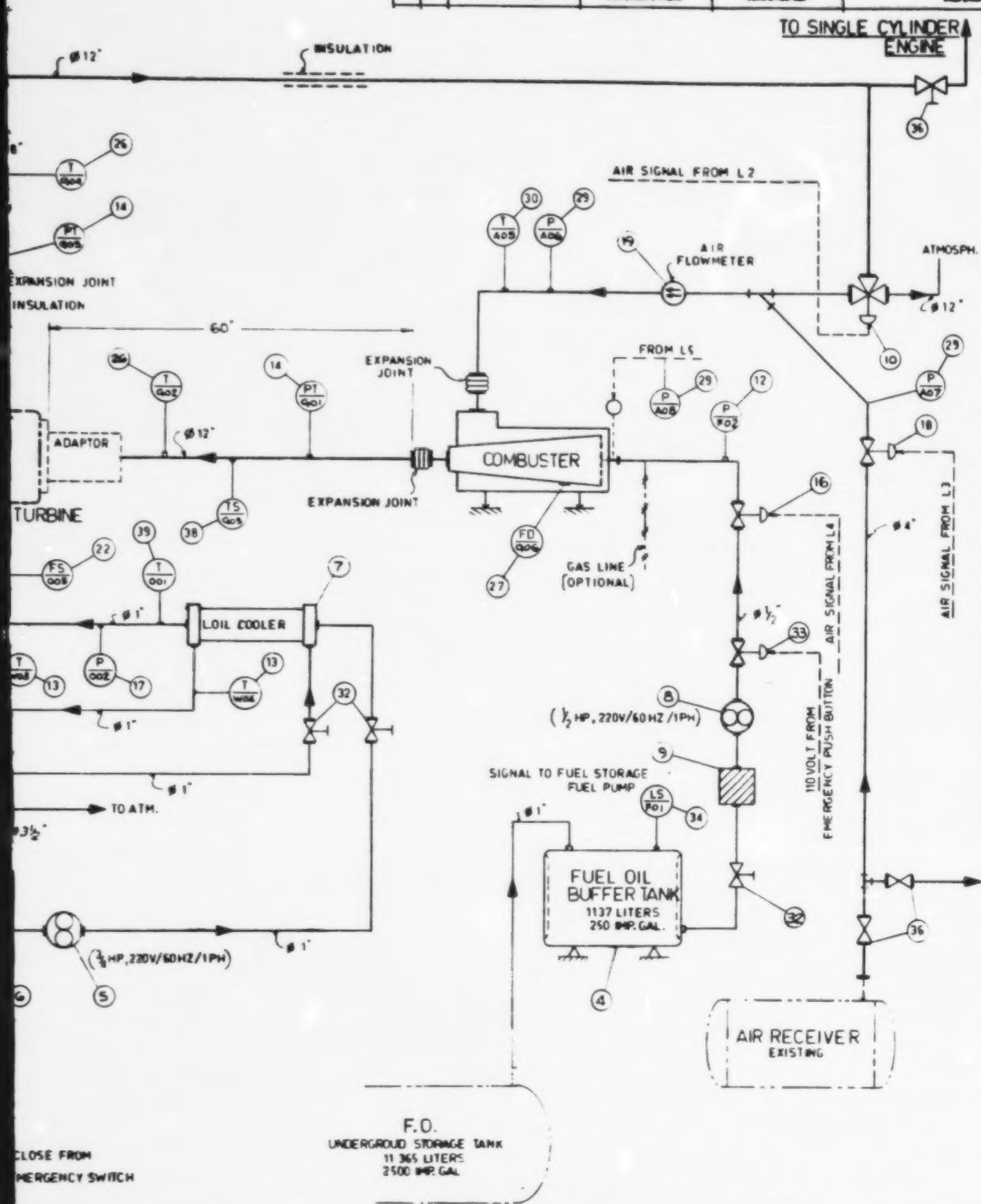
APPENDIX D TURBOCHARGER TEST RIG

Figure D.1 General circuit turbocharger test cell facility (drawing R94-057001)

Figure D.2 General arrangement turbocharger test cell facility (drawing R94-050015)

Table D-1 Start-up procedures turbocharger test rig (TTR)


SILENCER
AIR SIGNAL FROM L1
AIR FILTER
72"
COMPRESSOR
TURBINE
EXPANSION
INSULATION
ADAPTOR
OVERSPEED PROTECTION SIGNAL
WATER DRAIN
COOLING WATER
CONTROL ROOM
L1
AIR SIGNAL TO VALVE POSITIONER
3 PSIG/C , 15 PSIG/O
L2
AIR SIGNAL TO VALVE POSITIONER
3 PSIG/C. DUMP/O. SUPPLY
15 PSIG/C. SUPPLY/O. DUMP
L3
AIR SIGNAL TO VALVE POSITIONER
3 PSIG/C , 15 PSIG/O
3 - 15 PSI
TO
L4
AIR SIGNAL TO VALVE POSITIONER
3 PSIG/C , 15 PSIG/O
TO
L5
ATOMIZATION AIR
FOR FUEL INJECTION
30 PSIG
60 PSIG
LUB OIL SUMP
82 LITERS
110 VOLT SIGNAL TO CLOSE FRO
- PUSH BOTTON EMERGENCY
- SWITCH
FROM MAKE AIR SUPPLY PIPE



ITEM	DESCRIPTION
1	SILENCER
2	AIR FILTER
3	L.O. SUMP
4	F.O. TANK
5	L.O. PUMP
6	L.O. FILTER
7	L.O. COOLER
8	F.O. PUMP
9	F.O. FILTER
10	3 WAYS BUTTERFLY VALVE
11	BUTTERFLY VALVE
12	FUEL OIL PRESSURE GAUGE
13	WATER TEMP. TURBOCHARGER
14	AIR PRESSURE TRANSDUCER
15	LEVEL INDICATOR
16	F.O. SUPPLY MODULATING VALVE
17	LUB. OIL PRESSURE GAUGE
18	AIR MODULATING VALVE
19	AIR FLOWMETER
20	OVERSPEED DETECTOR
21	AIR SOLENOID VALVE 3 W.
22	L.O. FLOW SWITCH
23	HIGH OIL TEMP. SWITCH
24	COOLING WATER FLOW SWITCH
25	EXCESSIVE VIBRATION DETEC.
26	GAS TEMP. THERMOCOUPLE
27	FLAME DETECTOR
28	AIR PRESSURE REGULATOR
29	AIR PRESSURE GAUGE
30	AIR TEMP. THERMOCOUPLE
31	VALVE POSIT. LOADER REGU
32	MANUAL VALVE (LIQUID)
33	INDEPENDENT EMERGENCY S.V.
34	LEVEL SWITCH
35	
36	MANUAL VALVE (AIR)
37	SPEED PICK UP
38	TURBINE INLET TEMP. SWITCH
39	LUB. OIL TEMPERATURE
40	VACUUM GAUGE

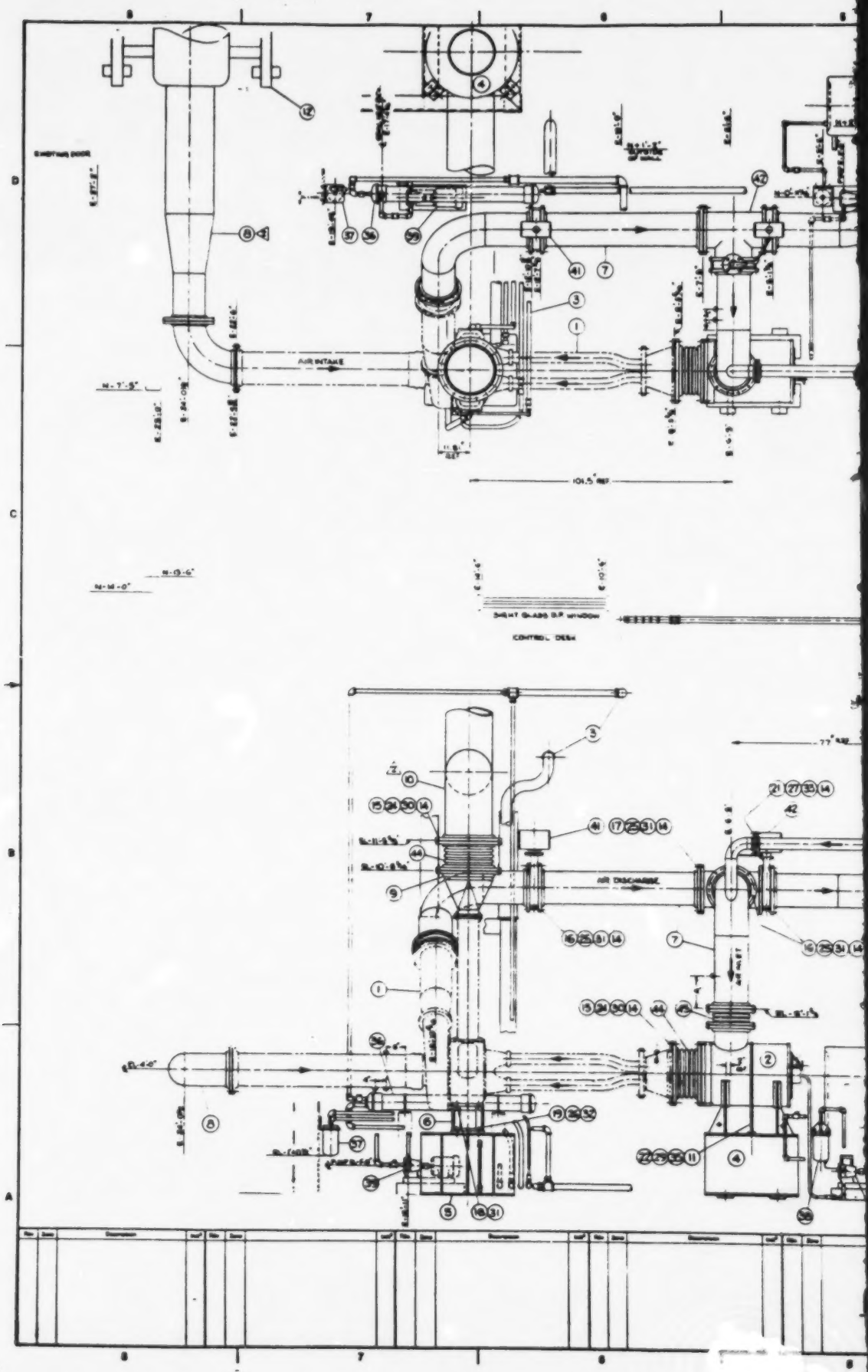
Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal Quebec Canada

GENERAL CIRCUIT
TURBOCHARGER
TEST CELL FACILITY

R94 - 057001

A1

FIGURE D.1


AIR INTAKE
AIR DISCHARGE
CONTROL DESK

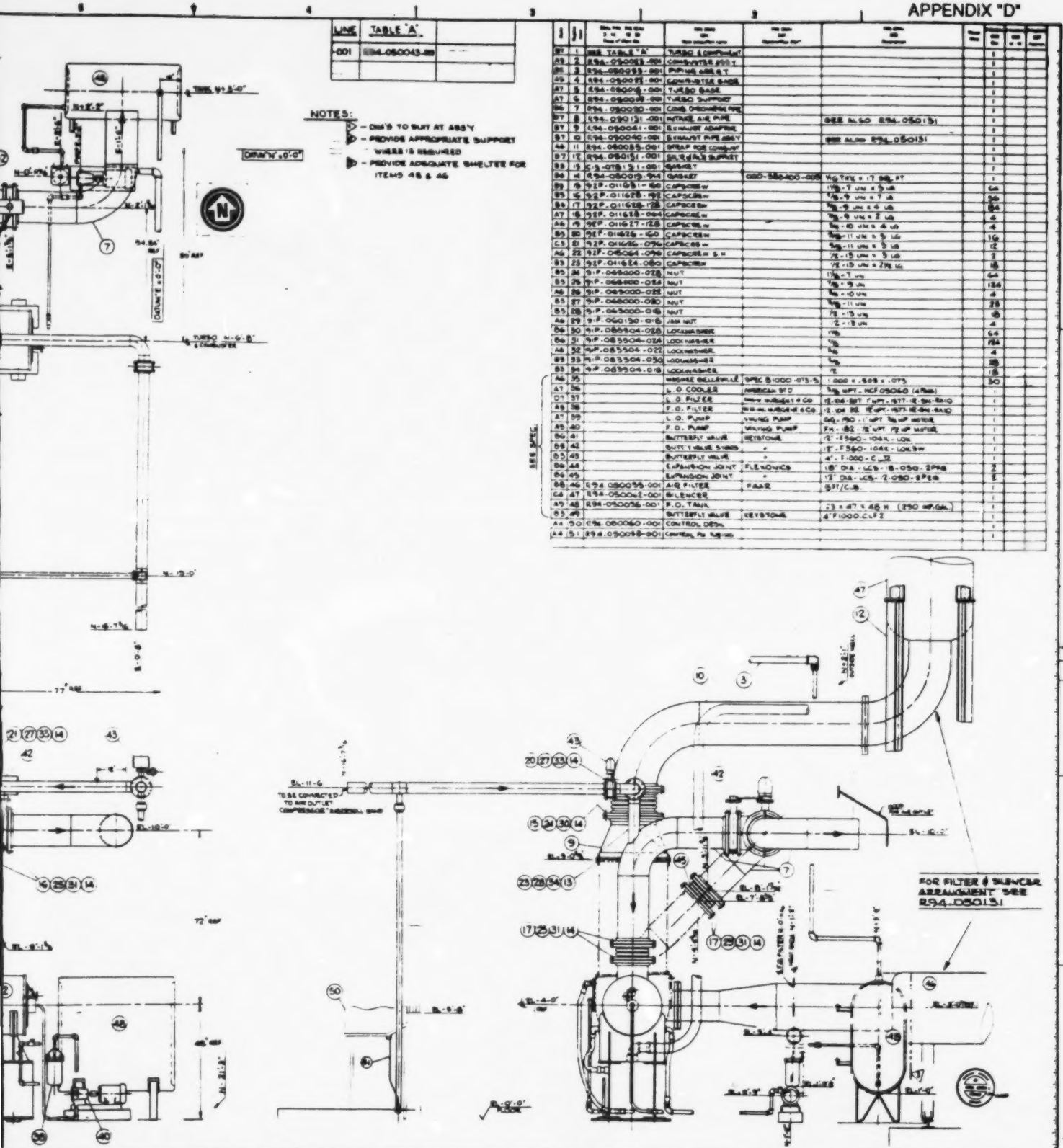


TABLE 'A'
NOTES:
DRAWN AT 0'-0"
TO BE CONNECTED TO AIR OUTLET
FOR FILTER & SILENCER ARRANGEMENT SEE R94-050131
GENERAL ARRANGEMENT
TURBOCHARGER TEST CELL FACILITY
R94-050015
FIGURE D.2

START-UP PROCEDURES
TURBOCHARGER TEST RIG (TTR)

1. Open all manual valves in air, water, oil, and fuel circuits.

2. Drain condensate from main air line.

3. Turn all main power switches and breakers to "ON" position.

4. On console #1; turn key to "POWER ON" position.

5. On console #1; depress blue "TEST" button (NOTE; this action checks all indicator lights and audible alarms. Blue light extinguishes after release of button).

6. Depress "CLEAR" button to stop audible alarm and flashing indicator lights.

7. Depress "RESET" button to re-arm alarm relay.

8. Depress button "WATER SOL" to start cooling water system.

9. Depress "OIL PUMP" button to start oil pump (NOTE; at this point check for leaks).

10. Ensure all four manually control valves (located on control panel, console #2) are set as follows:

    Valve #1: Fully opened (6 CCW turns from full closed position)

    Valve #2: Fully opened (6 CCW turns from full closed position)

    Valve #3: Fully closed

    Valve #4: Fully closed

11. Depress "AIR SOL." button (controls air to all pneumatic valves - verify pressure).

12. Depress "FUEL PUMP" button - verify pressure and check for leaks.

13. Depress "NOZZLE AIR" button - verify stable pressure.

14. Set fuel valve pressure to 28% opened. NOTE: This valve is controlled by two buttons; amber "TO CLOSE" and white "TO OPEN".

15. Start turbo spin. Turn valve four (located on front panel of console #2) slowly C.W until 300 RPM is reached.

    At this point should an emergency occur, depress red "EMERGENCY STOP" button (located on front panel of console #2) - or any one of four large yellow and red mushroom "STOP" buttons located in the test cell.

16. Set alarm limits of sigma meters. Setting obtained from test specifications.

17. Make sure igniter is not retracted.

18. Energize igniter. Depress "IGNITER" button.

19. Energize fuel solenoid. Depress "FUEL SOLENOID".

20. Observe gauge "Exhaust Temperature Combuster Out" (ETCBOT).

    Note - If temperature does not increase within ten seconds, shut fuel solenoid off and wait approximately five minutes then make second attempt.
    - Should second attempt fail, shut off igniter then depress "RETRACT SOLENOID" button.

21. To shut down TTR, de-energize "FUEL SOLENOID" then close valve #4 make-up air.

APPENDIX E ATOMIC ABSORPTION SPECTROPHOTOMETER

- Atomic Absorption Spectrophotometer

1 SYSTEM DESCRIPTION

The Perkin-Elmer Model 2380 is a microprocessor-controlled atomic absorption spectrophotometer which measures the concentration of metallic elements in a variety of matrices. It provides integrated readings in absorbance, concentration or emission intensity. The readings are integrated over a period selected by the operator from 0.2 to 60 seconds. When used with flameless sampling devices, the Model 2380 can also measure peak height or integrated peak area. Special keys are provided for calibration using up to three standards and a blank and for reslope of the calibration with a single additional standard if necessary. In addition, controls are included to facilitate automatic averaging and statistical treatment of results.

Using optional accessories, the readings can be presented on a laboratory recorder, printed on paper tape along with sample identification by the PRS-10 Printer-Sequencer, or typed in report form using the TR-2 Teletypewriter Readout. The TR-2 provides an output compatible with EIA specification RS-232C, which makes interfacing with computers or other data logging devices possible.

The Model 2380 is available in four assembly versions as shown in Table 1-1 below:

TABLE 1-1 - THE FOUR 2380 ASSEMBLIES AVAILABLE

Instrument Assembly	Interlocked Gas Controls	Digital Gas Controls	Back-ground Corrector	Wavelength Drive
Model 2380: 0060-0251 (105-125V,50/60 Hz) 0060-0252 (200-240V, 50 Hz)	●			
0060-0253 (105-125V, 60 Hz) 0060-0254 (105-125V, 50 Hz) 0060-0255 (200-240V, 50 Hz)	●		●	●
0060-0256 (105-125V, 50/60 Hz) 0060-0257 (200-240V, 50 Hz)		●		
0060-0258 (105-125V, 60 Hz) 0060-0259 (105-125V, 50 Hz) 0060-0260 (200-240V, 50 Hz)		●	●	●

For automated flame analyses, the microprocessor-controlled Model AS-50 Autosampler is available. The Autosampler enables automatic calibration to be performed with up to three standards, followed by the analysis of up to fifty samples.

For flameless analyses, the Model HGA-500 and HGA-400 Graphite Furnaces with microprocessor control are available. When combined with the Model AS-1 or AS-40 Autosampler automatic flameless auto sampling is possible.

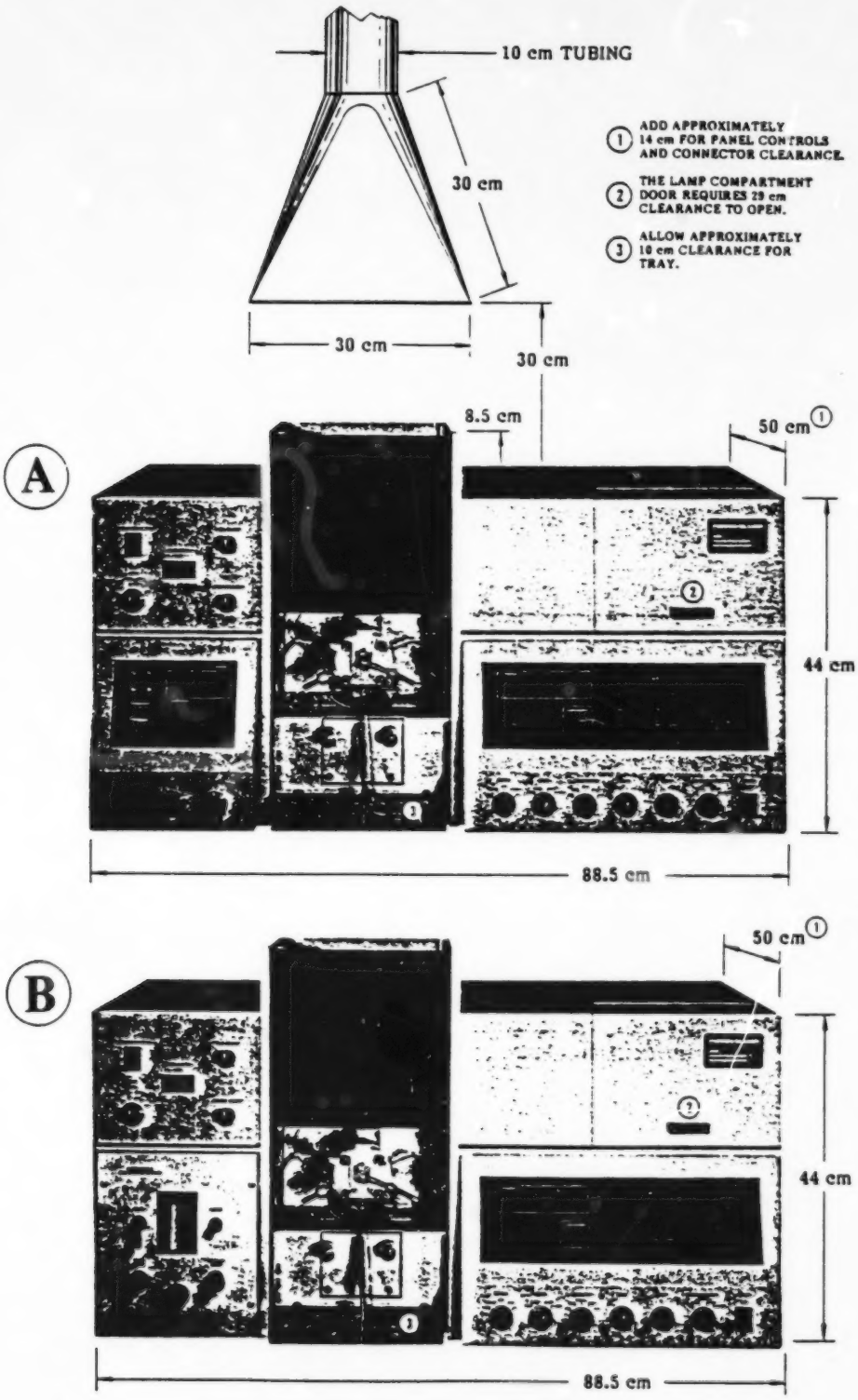


Fig. 2-1 - Dimensions of the Model 2380 Spectrophotometer

PERFORMANCE CHARACTERISTICS

The sensitivity of the instrument in detecting metallic elements is shown in Tables 5-1 and 5-2:

TABLE 1 - STANDARD CONDITIONS FOR ATOMIC ABSORPTION

ELEMENT	λ (nm)	SBW (nm)	FLAME GASES	SENS. CHECK(a)	ELEMENT	λ (nm)	SBW (nm)	FLAME GASES	SENS. CHECK(a)
Ag	328.1	0.7	A-Ac	3	Nd	463.4	0.14	N-Ac	500(b)
Al	309.3	0.7	N-Ac	45(b)	Ni	232.0	0.2	A-Ac	7
As	193.7	0.7	A-Ac	40	Os	290.9	0.2	N-Ac	45
As	193.7	0.7	N-Ac	45	P	213.6	0.2	N-Ac	15000
As	193.7	0.7	Ar-H	7	Pb	283.3	0.7	A-Ac	25
Au	242.8	0.7	A-Ac	12	Pd	247.6	0.2	A-Ac	12
B	249.7	0.7	N-Ac	2000	Pr	495.1	0.14	N-Ac	2500(b)
Ba	553.6	0.2	N-Ac	20(b)	Pt	265.9	0.7	A-Ac	90
Ba	553.6	0.2	A-Ac	225(b)	Rb	780.0	4.0	A-Ac	5(b)
Be	234.9	0.7	N-Ac	1.2	Re	346.0	0.2	N-Ac	700
Bi	223.1	0.2	A-Ac	18	Rh	343.5	0.2	A-Ac	15
Ca	422.7	0.7	A-Ac	3.5	Ru	349.9	0.2	A-Ac	25
Ca	422.7	0.7	N-Ac	2.5(b)	Sb	217.6	0.2	A-Ac	25
Cd	228.8	0.7	A-Ac	1.2	Sc	391.2	0.2	N-Ac	20(b)
Co	240.7	0.2	A-Ac	7	Se	196.0	2.0	A-Ac	25
Cr	357.9	0.7	A-Ac	4	Se	196.0	2.0	Ar-H	12
Cs	852.1	4.0	A-Ac	15(b)	Si	251.6	0.2	N-Ac	85
Cu	324.7	0.7	A-Ac	4	Sm	429.7	0.14	N-Ac	400(b)
Dy	421.2	0.2	N-Ac	40(b)	Sn	286.3	0.7	N-Ac	200
Er	400.8	0.2	N-Ac	45(b)	Sn	286.3	0.7	A-Ac	180
Eu	459.4	0.14	N-Ac	25(b)	Sn	286.3	0.7	A-H	70
Fe	248.3	0.2	A-Ac	6	Sr	460.7	0.14	A-Ac	6(b)
Ga	287.4	0.7	N-Ac	65	Sr	460.7	0.14	N-Ac	4(b)
Gd	407.9	0.2	N-Ac	800(b)	Ta	271.5	0.2	N-Ac	725
Ge	265.1	0.2	N-Ac	110	Tb	432.6	0.14	N-Ac	400(b)
Hf	286.6	0.2	N-Ac	700(c)	Tc	261.5	0.2	A-Ac	120
Hg	253.6	0.7	A-Ac	350	Te	214.3	0.2	A-Ac	45
Ho	410.4	0.2	N-Ac	50(b)	Ti	365.3	0.2	N-Ac	85
In	303.9	0.7	A-Ac	35	Tl	276.8	0.7	A-Ac	25
Ir	264.0	0.2	A-Ac	400	Tm	371.8	0.7	N-Ac	16(b)
K	766.5	4.0	A-Ac	1.8	U	358.5	0.2	N-Ac	2300(b)
La	550.1	0.2	N-Ac	2000(b)	V	318.4	0.7	N-Ac	75
Li	670.8	1.4	A-Ac	1.5	W	255.1	0.2	N-Ac	500
Lu	336.0	0.2	N-Ac	300(b)	Y	410.2	0.2	N-Ac	85(b)
Mg	285.2	0.7	A-Ac	0.3	Yb	398.8	0.2	N-Ac	5(b)
Mn	279.5	0.2	A-Ac	2.5	Zn	213.9	0.7	A-Ac	0.8
Mo	313.3	0.7	N-Ac	25	Zr	360.1	0.2	N-Ac	475
Mo	313.3	0.7	A-Ac	40					
Na	589.0	0.14	A-Ac	0.7					
Nb	334.4	0.2	N-Ac	1700(b)					

A-Ac = Air-Acetylene
N-Ac = Nitrous Oxide-Acetylene
Ar-H = Argon-Hydrogen-Entrained Air
A-H = Air-Hydrogen

(a) Metal concentration (µg/ml) in aqueous solution which will give a reading of approximately 0.2 absorbance units.

(b) Addition of a large amount of an easily ionizable material (e.g. 1000 µg/ml potassium as the chloride) required to control ionization.

(c) Fluoride added to obtain the sensitivity check value shown.

ANALYSIS OF LUBRICATING OILS

Determination Of Wear Metals

Introduction

This method describes the determination of wear metals in used lubricating oils. A number of elements, including aluminum, chromium, copper, iron, lead, magnesium, nickel, silicon, silver, tin and zinc can be determined.

Samples and standards are diluted to the desired concentration range with either methyl isobutyl ketone (MIBK) or xylene, after being adequately mixed to insure uniform dispersion of metal particles.

Cr, Fe, Ni and Si, if present as large supended particles, may not be measured by this method. The use of the N_2O-C_2H_2 flame will provide higher recoveries for Cr, Fe and Ni under these conditions. An acid digestion procedure for Fe and Ni is described in this section.

Typical Analytical Procedure

Sample Preparation

Mix samples by mechanical agitation for 5 minutes. Remove an aliquot of sample with a disposable syringe and dilute the sample 1:10 with either MIBK or xylene. If a more accurate analysis is required, oil aliquots should be measured on a weight basis rather than by volume. The dilution factor can be adjusted if working with very low or high concentrations.

NOTE: Silicon contamination may be a problem with certain types of plastic syringes.

Analysis

Determine the concentration of the elements of interest using the conditions listed in the "Standard Conditions" section. Cr, Fe, and Ni are best determined utilizing the N_2O-C_2H_2 flame. Working standards and blank solutions are prepared using the same dilution ratio of MIBK or xylene used for sample preparation. Standards are commercially available and can also be prepared using organo-metallic compounds. Refer to section 13 in the General Information section for additional information on standards.

BIBLIOGRAPHY

1. W. B. Barnett, H. L. Kahn and G. E. Peterson, At. Absorpt. Newsl. 10, 106 (1971). The Rapid Determination of Several Elements in a Single Lubricating Oil Sample by Atomic Absorption Spectroscopy.

2. T. T. Bartels and M. P. Slater, At. Absorpt. Newsl. 9, 75 (1970). Comparison of the Effectiveness of Emission Spectrographic and Atomic Absorption Techniques for Measuring Iron Particles in Lubricating Oil.

3. G. S. Golden, Appl. Spectrosc. 25, 668 (1971). The Determination of Iron in Used Lubricating Oil.

4. H. L. Kahn, G. E. Peterson and D. C. Manning, At. Absorpt. Newsl. 9, 79 (1970). The Determination of Iron and Chromium in Used Lubricating Oils.

5. R. H. Kriss and T. T. Bartels, At. Absorpt. Newsl. 9, 78 (1970). Improved Atomic Absorption Techniques For Measuring Iron Particles in Lubricating Oil.

ANALYSIS OF LUBRICATING OILS

Particle Size Independent Determination Of Wear Metals

Introduction

A number of wear metals, if present in large particles, are not quantitatively determined by atomic absorption if merely diluted with an organic solvent (MIBK or xylene). This method describes a procedure for acid digesting the metals. This method is suitable for the determination of aluminum, copper, iron, magnesium, molybdenum, nickel and titanium.

Oil samples and standards are mixed with an HF/aqua regia mixture and agitated in a heated ultrasonic bath until metal digestion is complete. The mixture is cooled and diluted with a methyl isobutyl ketone (MIBK)/isopropyl alcohol diluent. If Ti is not being determined, the HF can be omitted.

Other methods utilizing an acidified organic diluent for the determination of Fe (2), Mo (4), and Ti (3) can be used.

Typical Analytical Procedure

Sample Preparation

Mix samples by mechanical agitation for 5 minutes. Weigh 3 g of sample into a polyethylene bottle and add 0.4 g of a 1:20 HF/aqua regia solution. Shake mixture for 3-5 seconds. Place mixture into a heated ultrasonic bath (65° ± 5°C) for approximately 45 minutes. Cool and dilute with 5.6 g of a 1:10 MIBK/isopropyl alcohol solution.

NOTE: Aqua regia should not be used until evolution of gas has ceased.

For samples not containing Ti or if the presence of Ti is not important, omit the addition of HF.

Analysis

Utilizing the N_2O-C_2H_2 flame determine the concentration of the elements of interest according to the conditions listed in the "Standard Conditions" section. Standards and blanks are diluted with the 1:10 MIBK/isopropyl alcohol mixture. Standards are commercially available and can also be prepared using organometallic compounds. Refer to section 13 in the General Information section for additional information on standards.

BIBLIOGRAPHY

1. J. R. Brown, C. S. Saba, W. E. Rhine and K. J. Eisentraut, Anal. Chem. 52, 2365 (1980). Particle Size Independent Spectrometric Determination of Wear Metals in Aircraft Lubricating Oils.

2. R. H. Kriss and T. T. Bartels, At. Absorpt. Newsl. 9, 78 (1970). Improved Atomic Absorption Techniques for Measuring Iron Particles in Lubricating Oil.

3. C. S. Saba and K. J. Eisentraut, Anal. Chem. 49, 454 (1977). Determination of Titanium in Aircraft Lubricating Oils by Atomic Absorption Spectrophotometry

4. C. S. Saba and K. J. Eisentraut, Anal. Chem. 51, 1927 (1979). Determination of Molybdenum Wear Metal in Lubricating Oils by Atomic Absorption Spectrophotometry with a Particle Size Independent Method.

ANALYSIS OF LUBRICATING OILS AND ADDITIVES

Calcium, Barium, Zinc

Introduction

This method describes a procedure for the determination of calcium, barium and zinc in lubricating oils and lubricating oil additives, using an organic solvent (xylene) as a diluent. These elements can also be determined using a mixed-solvent system: Ca, Zn (3); Ba (2).

Samples and standards are diluted with xylene and made to contain approximately 0.3% potassium (as cyclohexanebutyrate). The addition of potassium controls ionization interferences for calcium and barium.

Typical Analytical Procedure

Sample Preparation

Mechanically agitate samples for 5 minutes. Weigh an appropriate amount of sample into a glass volumetric flask, add enough potassium (as cyclohexane-butyrate) so that the final volume contains 0.3% potassium. Dilute to volume with xylene. Adjust the dilution factor to insure that concentrations fall within a suitable absorbance range. If zinc is the only element to be determined, and is present in low concentration, a 0.1 g sample diluted to 25 mL may be suitable.

A 1% (w/v) potassium solution is prepared by dissolving 5.3 g of potassium cyclohexanebutyrate and 10 mL of 2-ethylhexanoic acid in 30 mL of xylene, with heating, and diluting to 100 mL with xylene.

Analysis

Determine the concentration of the elements of interest using the N_2O-C_2H_2 flame and the conditions listed in the "Standard Conditions" section. Standards are prepared using organometallic compounds. Standards and blanks are diluted with xylene using the same dilution ratio as that used for samples. Additional information regarding the preparation of organometallic standards is given in reference (4).

NOTE: When determining calcium and/or barium, samples, standards, and blanks should be made to contain 0.3% potassium (as cyclohexanebutyrate).

NOTE: If necessary, the sensitivity for Ca and Zn may be reduced by rotating the burner head 90° to the optical path.

BIBLIOGRAPHY

1. S. T. Holding and P. H. D. Matthews, Analyst 97, 189 (1972). The Use of a Mixed-Solvent System For the Determination of Calcium and Zinc in Petroleum Products by Atomic-absorption Spectrophotometry.

2. S. T. Holding, and J. J. Rowson, Analyst 100, 465, (1975). The Determination of Barium in Unused Lubricating Oils by Means of Atomic-absorption Spectrophotometry.

3. G. E. Peterson and H. L. Kahn, At. Absorpt. Newsl. 9, 71 (1970). The Determination of Barium, Calcium, and Zinc in Additives and Lubricating Oils using Atomic Absorption Spectrophotometry.

4. National Bureau of Standards Monograph 54, October 1962. Analytical Standards for Trace Elements in Petroleum Products.

ANALYSIS OF GASOLINE

Lead

Introduction

This method describes the determination of lead in gasoline. Alkyl lead compounds are stabilized by reacton with iodine and a quaternary ammonium salt (Aliquat 336). Aliquat 336 (tricapryl 1 methyl ammonium chloride) is manufactured by General Mills Chemicals, Inc., Minneapolis, MN, and distributed by the McKesson Corp, Minneapolis, MN.

Samples are mixed with MIBK and allowed to react with an iodine solution (3% (w/v) iodine/benzene) and a 1% (v/v) Aliquat 336/MIBK solution. Lead chloride ($PbCl_2$), 10% (v/v) Aliquat 336/MIBK, 1% (v/v) Aliquat 336/MIBK, 3% (w/v) iodine/benzene, and lead-free gasoline or iso-octane (trimethyl pentane) are used to prepare standards.

Typical Analytical Procedure

Sample Preparation

To a 50-mL volumetric flask, add approximately 30 mL of MIBK. Pipet 5 mL of the gasoline sample into the flask and mix. Add 100 µL of the 3% iodine solution and allow the mixture to react for about 1 minute. Pipet 5 mL of the 1% Aliquat 336/MIBK solution into the flask and mix. Dilute to volume with MIBK and mix well. The dilution ratio can be adjusted to insure that concentrations fall within a suitable absorbance range.

Analysis

Determine the concentration of lead using the conditions listed in the "Standard Conditions" section.

Standard And Blank Preparation

Stock lead solution, 5.0 g Pb/U.S. gallon. Transfer 0.4433 g of lead chloride (previously dried at 105°C for 3 hours) to a 250-mL volumetric flask and dissolve in approximately 200 mL of 10% Aliquat 336/MIBK solution. Dilute to volume with the 10% Aliquat 336/MIBK solution, mix well, and store in a glass bottle. This solution contains 1321 mg Pb/L, which is equivalent to 5.0 g Pb/U.S. gallon.

Intermediate stock solution, 1.0 g Pb/U.S. gallon. Pipet 50 mL of the stock lead solution into a 250-mL volumetric flask, dilute to volume with the 1% Aliquat 336/MIBK solution and store in a glass bottle.

Intermediate lead standards, 0.02, 0.05 and 0.10 g Pb/U.S. gallon. Pipet 2, 5 and 10 mL of the intermediate stock solution into 100-mL volumetric flasks. Add 5 mL of the 1% Aliquat 336/MIBK solution to each flask, dilute to volume with MIBK and store in glass bottles.

Preparation of working Pb standards and blank. To each of four 50-mL volumetric flasks, add approximately 30 mL of MIBK. Pipet 5 mL of the appropriate intermediate lead standard and 5 mL of lead-free gasoline into the flasks. For the blank, add only 5 mL of the lead-free gasoline. Add immediately 100 µL of the 3% (w/v) iodine solution and mix well. Add 5 mL of the 1% Aliquat 336/MIBK solution and mix. Dilute to volume with MIBK and mix well.

NOTE: Lead-free gasoline contains less than 0.001 g Pb/U.S. gallon. If a suitable lead-free gasoline is not available for the preparation of the blank and working standards, iso-octane (trimethyl pentane) may be used as a substitute.

BIBLIOGRAPHY

1. American Society for Testing Materials (ASTM). Standard Method D3237, Test for Lead in Gasoline by Atomic Absorption Spectrophotometry.

2. M. Kashiki, S. Yamazoe and S. Oshima, Anal. Chim. Acta 53, 95 (1971). Determination of Lead in Gasoline by Atomic Absorption Spectrophotometry.

ANALYSIS OF FUEL OILS

Vanadium, Sodium, Lead

Introduction

This method describes the determination of vanadium, sodium and lead in various types of fuel oils and may be applicable to the determination of other metals. Samples and standards are diluted with xylene.

Typical Analytical Procedure

Sample Preparation

Weigh 5 g of sample in a 50 mL volumetric flask. Dilute to volume with xylene and mix. The dilution factor can be adjusted to insure that concentrations fall within a suitable absorbance range.

Analysis

Determine the concentration of the element of interest using the conditions listed in the "Standard Conditions" section. Standard are commercially available and can also be prepared using organometallic compounds. Standards and blank solutions are prepared by diluting with xylene using the same dilution ratio used for sample dilution. For additional information on organo-metallic standards, refer to section 13 in the General Information section.

ANALYSIS OF GAS OILS

Introduction

This method describes the determination of nickel in gas oils by the method of additions procedure. This method is also applicable to copper, iron and several other elements. Nickel present in large particles may not be determined by this method.

Typical Analytical Procedure

Sample Preparation

Pipet 5-mL aliquots of sample into each of five 25-mL volumetric flasks. Add 0, 0.25, 0.5, 1.0 and 1.5 mL of a 5 mg/L nickel working standard and dilute to volume with xylene. For a more accurate analysis, the sample can be measured by weight (5 g instead of 5 mL).

Analysis

Determine the concentration of nickel using the conditions listed in the "Standard Conditions" section and the Method of Additions procedure described in the General Information section. A stock standard is prepared by dissolving thoroughly dried nickel cyclohexanebutyrate (NBS Standard 1065 a or equivalent) in nickel-free white oil, or lubricating oil (2). Instructions for this procedure are provided with the nickel cyclohexanebutyrate. A working standard (5 mg/L Ni) is prepared by diluting an appropriate amount of the stock standard in xylene.

NOTE: A background corrector should be used to correct for background absorption when determining Ni.

BIBLIOGRAPHY

1. J. D. Kerber, Appl. Spectrosc. 20, 212 (1966). Direct Determination of Nickel in Catalytic-Cracking Feedstocks by Atomic Absorption Spectrophotometry.

2. National Bureau of Standards Monograph 54, October 1962. Analytical Standards for Trace Elements in Petroleum Products.

3. D. Trent and W. Slavin, At. Absorpt. Newsl. 3, 131 (1964). Direct Determination of Trace Quantities of Nickel in Catalytic Feedstocks by Atomic Absorption Spectrophotometry.

ANALYSIS OF PETROLEUM ADDITIVES

Lead And Antimony

Introduction

This method describes the determination of lead and antimony in petroleum additives. Samples and standards are diluted with methyl isobutyl ketone (MIBK) and made to contain 10% (v/v) 2-ethylhexanoic acid (a solubilizing agent).

Typical Analytical Procedure

Weigh 1 g of sample into a 250-mL beaker and dissolve in 75 mL of MIBK. Add 100 mL of 2-ethylhexanoic acid, transfer quantitatively to a 1 liter volumetric flask and dilute to volume with MIBK. The dilution factor can be adjusted to insure that the sample concentrations fall within a suitable absorbance range.

NOTE: Samples, standards and blanks should be made to contain 10% (v/v) 2-ethylhexanoic acid.

Analysis

Determine the concentration of the elements of interest using the conditions listed in the "Standard Conditions" section. Standards are prepared from lead diamyldithiocarbamate, and antimony dialkyldithiocarbamate, and diluted with MIBK.

BIBLIOGRAPHY

1. G. R. Supp, At. Absorpt. Newsl. 11, 122 (1972). Determination of Antimony in Petroleum Additives Using Atomic Absorption Spectrophotometry.

2. G. R. Supp, I. Gibbs and M. Juszli, At. Absorpt. Newsl. 12, 66 (1973). Determination of Lead in Petroleum Additives Using Atomic Absorption Spectrophotometry.

3. M. S. Vigler and V. F. Gaylor, Appl. Spectrosc. 28, 342 (1974). Trace Metals Analysis in Petroleum Products by Atomic Absorption.

This manual describes the procedures the operator of the Model 2380 needs to run the instrument. Sections 2 and 3 provide installation procedures (although the instrument is usually installed by a Perkin-Elmer Service Representative) and information on material and equipment needed to set up an atomic absorption instrument in the laboratory. Information on principles of operation, performance characteristics and specifications for the Model 2380 is provided in Sections 4, 5, and 6. Operating instructions are given in Sections 7, 8 and 9, and calibration is described in Section 10. Servicing and maintaining the instrument and troubleshooting advice are discussed in Sections 12 and 13. Error messages are explained in Section 14 and instructions for the Interlocked Gas Control are provided in Appendix 1.

The following publications are used in conjunction with this manual and, with the two exceptions noted, are provided with the instrument or can be obtained free of charge from Perkin-Elmer.

1. "Preparing Your Laboratory for Perkin-Elmer Atomic Absorption Spectrophotometers" (Brochure L-301). This brochure is included in this manual (Section 3).

2. "Atomic Absorption Spectroscopy" by W. Slavin, Wiley and Sons, 1968. This book is available from Perkin-Elmer. Order part no. 0990-9628.

3. "Atomic Absorption Spectroscopy" by B. Welz, Verlag Chemie, 1976. Available from Perkin-Elmer, Part No. 0993-9462.

4. "Analytical Methods for Atomic Absorption Spectrophotometry" (part no. 0303-0152) is provided with the instrument.

5. Flameless sampling techniques with an HGA Graphite Furnace are discussed in the HGA instruction manuals and in "Analytical Methods for Atomic Absorption Spectroscopy Using the HGA Graphite Furnace" (part no. 0990-9972). These manuals are supplied with the HGA accessory.

6. Atomic Spectroscopy. A free one-year subscription is provided to the purchaser of an atomic absorption instrument.

7. "Concepts, Instrumentation and Techniques in Atomic Absorption Spectrophotometry" by R.D. Beaty. A copy is supplied free with each instrument.

The Model 2380 is listed with the U.S. Food and Drug Administration as an IVD Instrument. This manual contains information required by the FDA for such instruments.